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CONTENTS

(The Contents of SCIENCE EDUCATION are indexed in the Education Index)

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SCIENCE EDUCATION

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FIELD EXCURSIONS IN GEOLOGY

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During the past spring it was my duty to interview a number of candidates for admission to Columbia College. One of them, a High School graduate from Brooklyn, had never been outside of New York City. He had never been to Staten Island, and had never crossed the Hudson to New Jersey. Think for a moment what this means. He had never been on a railroad train, except the subway. He had never been on a boat, for he had never used the ferry. He had never seen a hill, a mountain, a forest, a river of running water. I dare say he had seen but few of our domestic farm animals. And yet this same individual with his excellent scholastic record has been admitted to Columbia University and in a period of four years, unless he has elected a course in Geology, he will still have had no reason to venture away from the big metropolis. He will be granted an A. B. degree and will be deemed to have had a "liberal education" as that term is now generally understood in academic circles.

About one-fifth of the men entering Columbia College elect the introductory course in General Geology. Hundreds of these men during the past eighteen years have become personally known to me and I am therefore in a position to state that a large proportion of them have never travelled far beyond the metropolitan area of New York. In view of this situation the introductory course in Geology at Columbia has for the past 25 years or more substituted Field Trips entirely for all laboratory requirements. Those who eventually specialize in Geology receive their laboratory training in their later courses. A 3-day Field Trip each semester to points as far distant as southern Pennsylvania and the Adirondacks have been acclaimed by the students for the opportunity thus provided for attaining a broad perspective not only of Geology but of man's activities in the world outside of the classroom.

I propose here to make a few observations about *Field Excursions in Geology* as a result of my experiences with classes of many kinds and with trips of varying lengths, even to those of several months.

First of all, I would like to consider *Field Trips* from the standpoint of the objective to be attained. As I see it there are two types of field trips: the first designed to demonstrate (or to discover) the principles of the subject; the second, to convey a regional picture. Both of these objectives may of course be undertaken at the same time. Let us dwell for a moment upon the distinction just made, for it lies at the root of the whole matter. A trip to an outcrop, an afternoon's excursion involving the drawing of a section perhaps, or mapping a detail, or even a several days' trip designed to work out a particular aspect of a problem, these are all intended to throw some light upon a principle of Geology, or some kind of fundamental generalization. This principle may eventually enable the student to understand better the particular region involved, as

well as contribute to his grasp of Geology as a whole. Principles thus learned may then be applied elsewhere, presumably anywhere in the world. Such principles and facts acquired in this manner may be compared with the words and syntax which must be learned before a child can read English or any other language. They are like the notes and scales of music, or like the rules of perspective in art. But it should be remembered that they are only the tools. The masterpiece itself, the great play or drama or essay, the symphony, the great painting, it is these toward which these basic ideas are preparing the way. And so in our field trips it is not the individual facts and principles which count so much as the ensemble, the combination of them all. Together they make up the region and until the details of the region are integrated to form a complete picture the function of field trips is not adequately satisfied.

A child taught only to spell words or to parse sentences must as soon as possible be given the whole book or story until he is beguiled by its plot, and is carried along by the spirit and charm of the tale itself. The young musician should hear great orchestras, and the young artist should see great pictures even though much of their significance may for a time be lost upon him. And so it is also with the young student of geology, and especially with him who is never going to be a geologist. He should as soon as possible see landscapes in their entirety. He should apprehend not only what can be encompassed in one limited view but also the pattern of the whole region or country. To look at things in this expansive way is not natural to most of us, particularly to the city man. Short field trips to individual and disconnected localities are perhaps in many cases the most expedient kind of field trips to conduct, but sooner or later it is important that they all be correlated. The selection of localities must therefore take into account the ultimate aim of providing a comprehensive picture of the whole area. For thus even a locality of seemingly little note gains interest when it becomes part of a larger picture.

And now a few words concerning the plan of the excursion itself. No matter how it is done, there will be found certain advantages in any chosen method. Take a simple afternoon's trip for example. The instructor may, prior to the occasion, give the class a fairly complete statement of what is to be expected, thus saving considerable time in the field where conditions for lecturing are not always favorable. The student in this way is prepared for what he is to see and is apt to feel more at ease and better satisfied with the outcome. With a class of young and inexperienced people I am inclined to think that this is a good procedure. On the other hand, a skillful instructor can take a class to an outcrop or other point of interest with no preliminary remarks whatsoever and let the class try for themselves to explain what is before them. This method has much to commend it too, but it must be realized that far more time will in that case have to be spent in the field. Many useless digressions will have been engaged in before the correct explanations have finally been made clear to the class. Constant note-taking by the students will be discouraged because of the many changes and alterations which turn out to be necessary. This approach is what might be called the inductive one, leading from the detailed observations to the broader generalizations and explanations. The opposite method might be termed the deductive approach, for in that case the student starts off with the broader concepts in mind and into them fits the details as they are brought to his attention. For older students backed by a little experience, and particularly with smaller groups, the inductive approach is stimulating and tends to introduce large numbers of topics for discussion. An entire afternoon can thus be spent upon what might at first seem to be a trivial bit of interest. But in the end the instructor will have been forced to draw upon much of his past experience

and knowledge. The students themselves will have provided the moving force by the many questions which will have come to their minds. So it will be seen that each of these two opposing methods is admirable in its own way. The farsighted teacher will therefore plan his excursions so that the method most appropriate to the situation will be used.

It can hardly be expected, in the limited time available for a course in Geology, that a broad regional picture can be attained by the methods set forth above. To do this it will be necessary to study descriptions and maps that together make up the literature of the subject. This is where the instructor plays the rôle of guide and in as masterly a fashion as possible selects from all available sources the material which will best put before the student the broader facts and principles concerning the region as a whole. With this preparation the student is ready for his longer excursions. The mental pictures of the region gained from the study of maps and descriptions in the classroom are thus corrected in the out-of-doors and brought into line with the objects themselves. Every observation in the field must be fitted into the bigger picture, a procedure which is largely deductive. The knack of seeing in every landscape the relation which it bears to the regional pattern of the country is the key to the appreciation of scenery. How many millions of us there are to whom all hills are alike and to whom travel is little more than getting from one town to another. Indeed, the value of field excursions as part of a liberal education is not fully appreciated by those to whom it has been denied. One of our leading professors of philosophy recently suggested to me that in his opinion field trips are a waste of time because the same end could be gained by moving pictures in the classroom. It is perhaps possible to learn how to appreciate great music from phonograph renderings, or great paintings from reproductions, but in geology pictures are poor substitutes for the landscapes themselves. Somewhere in every student's experience there should be given the opportunity to learn by direct observation the significance of geological phenomena for then, with this background, pictures of scenery will take on an added meaning.

Geological excursions and indeed other kinds of excursions serve a broader purpose than that for which they are explicitly designed. It has been observed that in order to learn most about a country, it is necessary to visit that country with a certain narrow objective. The visitor to Spain, for example, will learn more about Spain if he goes there to find out what he can about Spanish geology, or Spanish art, or Spanish architecture, or Spanish history, or Spanish industry. Any one of these outlooks may serve as the window through which Spain may be viewed, and more will be seen by looking intently through one of these windows than in trying to look through all of them at once. Field trips in geology thus create a desire to understand such matters as the botany and ecology of a region, its human activities including its past history and even its literature. Geology is, perhaps, as well able to do this as any other subject that might be chosen. It seems from my limited and prejudiced point of view that almost all things depend in some way upon the geological nature of the region. I hope that teachers in other fields will feel the same way about their own subjects. It would not be amiss then for every instructor, both indoors and out-of-doors, to focus attention for a moment upon the many facets of his subject, bringing in here and there apt remarks upon biological, historical, and economic relationships. Each science in this way can become a general science in itself and thus deserve to be considered a true exponent of culture. It would be well for teachers of the kind just indicated to assume that no members of the class will eventually become specialists in his particular field. None of them, let us say, will become ge-

ologists whereas many of them will hold influential places in world affairs where an appreciation of these relationships becomes important. The responsibility of the teacher of Geology, as of every teacher, is therefore great. His vision should extend beyond the mere scientific explanation for the origin of topographic forms or for any of the geological phenomena under observation. He should be carried far beyond this point and trained to see the implications of the subject. The specialist, bent on discovering more and more about less and less, finds it hard to sacrifice his scientific reputation in digressions such as I have suggested. The true research scholar is distressed when he is not going deeper into an explanation of underlying principles, and this tends to put him out of sympathy with the student whose interests with geology are only limited. The instructor who conducts a course in General Geology could well take it as his scholarly duty to discover all the ramifications by which geology intrudes itself into other fields of endeavor and somewhat emphasize these in his discourses. In doing this, he will not be acclaimed by geologists nor will he benefit from any personal rewards because his success in doing this is not easily measured. And yet as a purveyor of "liberal education" it is his bounden duty to overstep his field. Indeed he may be said to succeed only to the extent that he submerges geology in favor of the larger and composite picture. A teacher of this caliber may be described not as a teacher of geology but as a teacher of men. Geology only happens to be the tool through which he works.

THE MEASUREMENT OF ABILITY TO APPLY PRINCIPLES OF PHYSICS IN PRACTICAL SITUATIONS

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THE development of the ability to apply understandings of the principles of physics in practical out-of-school situations is one of the major objectives of instruction in high school physics. The extent to which this objective is, or can be, realized as a result of classroom experience is conditioned by the availability of reliable means for determining progress toward the attainment of the objective.

While some progress has been made toward the building of special tests designed to measure the ability to apply principles in situations closely related to life, most of the tests which are used by physics teachers continue to place major emphasis on informational learning and the ability to work numerical problems similar to those found in text books. The latter being representative of types on which ample drill is usually given and frequently requiring nothing more than the substitution of numerical values in formulae which may easily be memorized by pupils. The general acceptance of the ability to apply principles as an objective of instruction in physics when contrasted with the continued prevalence of tests of the informational type seems to indicate that many teachers of physics are assuming that the possession of a wide range of information in physics and the ability to work type problems is an indication of an equally well developed ability in the application of principles. It has been the purpose of this study to further investigate the validity of this assumption.

THE PROBLEM

The major problem of this study, therefore, may be stated as follows: What is the relationship between the ability (or abilities) involved in both the recall of informa-

tion and the solution of conventional problems in physics and the ability to apply principles of physics in the solution of problematic situations which are typical of out-of-school experiences?

Two subsidiary problems which have some bearing on the major problem were also studied: (1) How are each of the abilities which are designated in the major problem related to intelligence? (2) How are each of these abilities related to final grades in courses in high school physics?

RELATED STUDIES

Several studies which have been reported within the past two decades reveal evidence which indicates a lack of agreement with respect to the relationship between abilities which are closely related to those which have been investigated in this study. Tilton measured the relationship between "Association" and the "Higher Mental Processes". He defined "Association" as "a mental process by which a familiar stimulus leads to a learned and more or less habitual response", and "Higher Mental Processes" as those mental processes "by which novel stimulus situations are correctly responded to".[1]

In the Tilton study a battery of three published tests relating to vocabulary and arithmetic habits was used to measure association and another battery of three tests emphasizing arithmetic relationships was used as a measure of Higher Mental Processes. As a result of the comparison of the self correlations and inter-test correlations obtained, Tilton concluded:

> We find in our data no clear evidence of any distinction (sharp or otherwise) between extent of association and the efficiency of the Higher Mental Processes.[2]

In a much more recent study, Howard utilized the judgments of experts in rating the items of the Cooperative General Science Test for college students, Form 1937, in the order of increasing complexity. On the basis of this rating, he constructed a series of five subtests representing progressively increasing levels of complexity. The tests returned by 400 college sophomores were then analyzed to secure subtest results. Coefficients of correlation corrected for attenuation were computed and compared for all possible intercorrelations among the subtests. As a result of this analysis Howard states:

> One can find in this data little to support the thesis that the ability to organize and use facts to make applications, is of a different order from the ability to recall specific facts. Organizing ability in a field of knowledge appears indistinguishable from extent of information in that field. There does not appear to be any large group of fact getters who are unable to make use of these facts.[3]

The definition of Association given by Tilton seems to agree quite well with the abilities tested at the lower subtest levels of the complexity scale devised by Howard. Likewise, the Higher Mental Processes as defined by Tilton seem almost identical with abilities measured by the upper subtests of Howard's complexity scale. The combined evidence of the two reports, therefore, supports the conclusion that one should expect no significant difference between abilities which may be measured by the informational type of test and the ability to apply principles in situations which are relatively new to the pupil.

However, there have been other studies reported in recent years which present evidence supporting the contention that the abilities in question are distinctly different. In a well known study by Tyler the relationship between the ability to recall information and the ability to recall and apply principles in new situations was investigated in a number of college courses in-

[1] Tilton, J. W., *The Relation Between Association and the Higher Mental Processes*, Bureau of Publications, Teachers College, Columbia University, 1926. Page 1.

[2] *Ibid.*, page 48.

[3] Howard, Frederick Thomas, *Complexity of Mental Processes in Science Testing*, Bureau of Publications, Teachers College, Columbia University, New York City, 1943, page 44.

cluding a considerable number of science courses. In this study coefficients of correlation corrected for attenuation were computed for each course, between tests designed to measure the respective abilities. Tyler's interpretation of the experimental results follows:

> An examination of the coefficients of correlation reported makes it clear that in none of the widely varying courses in which tests were given was there a perfect relation between recall of information taught in a course and recall and application to new situations of principles learned in the course. The highest coefficient of correlation corrected for attenuation is only .58. Most of the corrected coefficients are close to .45. . . . Since the two types of tests require recall of information and one required application in addition to recall, the relatively low correlations show clearly that application is a mental process different from mere recall.[4]

Kilgore set up a special classroom procedure to place emphasis on the teaching of principles of physics. In order to measure the effect of his technique on the ability of pupils to apply principles in new situations, he constructed a test in which each item was based on an out-of-school problem situation. The reliability of this test was found to be .70. Both the principles test and the Cooperative Physics Test, Form 1934, were given before and after the experimental period and the gains analyzed statistically. The conclusions drawn as a result of this experiment include the following statement:

> The Principles Test identified an ability which was not measured by the Cooperative Test. This is indicated by the relatively small difference on the Cooperative Test (.799 S. D.), as contrasted with the very large gain on the Principles Test (5.75 S. D.). The low coefficient of correlation between the scores on the two tests also tends to support this conclusion (.45±.06).[5]

As a part of a study designated to evaluate student achievement in a college survey course in physical science, Brewer constructed a test to measure the ability of students to apply science information in new situations. This test, the content of which was limited to material on astronomy, was administered at the close of the astronomy unit and the resulting scores were compared with scores of the same students on both an information pre-test and post-test. The resulting correlations were, respectively, .41 and .51.[6]

While the reliability coefficient of the test of ability to apply was not determined, the reliabilities of the pre-test and post-test were, respectively, .79 and .65.[7] These figures seem to suggest a considerable difference between information and the ability to apply this information as these factors were measured in this study.

In an effort to determine the relative abilities of pupils at different grade levels to arrive at an understanding of certain concepts relating to power, Bailey gave both a facts test and a test "composed of statements of principles" to pupils at elementary, junior high school and senior high school levels. His findings which are pertinent to the present study are summarized as follows:

> The reliability measure of the facts test was .936 (σ=14.58) and ($^{\sigma}\sigma._{1}$=3.688). The reliability measure of the principles test was .923 (σ=15.82 and $^{\sigma}\sigma_{1}$=4.39) consequently $r_{1,2}$ of .791 between facts and principles indicates a lack of dependence between these two variables.[8]

Evidence revealed by the reports of Tyler, Howard, Kilgore, and Bailey supports the general conclusion that the ability to apply principles to new situations cannot be effectively measured by tests which are predominately of the informational type. This is in direct contrast with the findings

[4] Judd, Charles H., *Education as Cultivation of the Higher Mental Processes,* The Macmillan Company, New York, 1936, pages 12 and 13.

[5] Kilgore, William Arlow, *Identification of Ability to Apply Principles of Physics,* Bureau of Publications, Teachers College, Columbia University, New York, 1941, page 18.

[6] Brewer, Waldo Lyle, *Factors Affecting Student Achievement and Change in a Physical Science Survey Course,* Bureau of Publications, Teachers College, Columbia University, New York, 1943, page 42.

[7] *Ibid.*, page 30.

[8] Bailey, Ralph G., "The Difficulty Level of Certain Science Concepts," *Science Education,* 25:84–89, February, 1941.

of Tilton and Howard. While no attempt has been made to make the preceding summary of related investigations exhaustive, it is apparent that a disagreement of research findings exists. This fact justifies further study of the problem and has motivated the selection of the experimental design employed in the present investigation.

THE METHOD

The method employed in this investigation includes three procedures which have been selected with a view to increasing the reliability of the results obtained.

(1) The scope of subject matter covered by each test designed to measure information and facility in the solution of conventional problems in physics is approximately identical with that of the corresponding test of ability to apply.

(2) Duplicate pairs of tests, which were administered to duplicate groups of pupils, have been employed throughout the study. Thus the report includes the results of parallel investigations conducted simultaneously.

(3) The correlation coefficients reported are *within schools* correlations, the effect of school differences in central tendency having been removed through utilization of the method of analysis of covariance.

Construction of Tests

It was considered to be desirable that the individual items of the tests which have been employed in this study should be based upon principles of physics, an understanding of which is of importance for general education. For this reason, forty principles, including ten in mechanics, ten in heat, ten in electricity, and ten in light and sound, were selected from the first one-hundred sixty of the list of two-hundred sixty-four principles of physical science developed by the writer as a result of an earlier study.[9, 10]

[9] Wise, Harold E., "A Determination of The Relative Importance of Principles of Physical Science for General Education," *Science Education*, 25:371–379, Dec. 1941, and 26:8–12, Jan. 1942.

[10] Wise, Harold E., "A Synthesis of The Results of Twelve Curricular Studies in the Field of Science Education," *Science Education*, 27:36–40, Feb. 1943, and 27:67–76, Sept.–Oct. 1943.

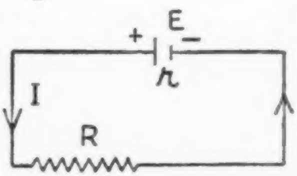
Each principle selected served as a basis for the construction of six test items of the multiple choice type. Two of these six items are intended to require the ability to select answers representing correct statements of information which is usually associated with the development of the principle by qualified teachers or in standard text books. Each of two other items are intended to require the ability to solve a conventional numerical problem involving the principle. Whenever possible this problem is one which can be readily solved through use of a formula. Finally two items were constructed in each of which a situation is described which is considered to be typical of those situations normally encountered in everyday life, and which requires an understanding of the principle for its correct solution or interpretation. Following this description of the situation a choice of answers or solutions are given, one of which is correct, while the others are designed to "catch" the pupil with a superficial or incorrect understanding of the principle.

The test items associated with a single principle selected at random follow:

Principle—The electrical current flowing in a conductor is directly proportional to the potential difference and inversely proportional to the resistance.

Informational Items.

1. If we let I represent current, E electromotive force, and R the total resistance of an electric circuit, we may represent Ohm's law as follows: (1) $E=\frac{I}{R}$, (2) $I=\frac{E}{R}$, (3) $R=\frac{I}{E}$, (4) $I=ER$, (5) $R=IE$.

2. 

In the circuit shown ~~at~~ the left, above the total current I could be increased by (1) decreasing the electromotive force E, (2) increasing the internal battery resistance r, (3) decreasing the external

resistance R, (4) increasing the external resistance R, (5) increasing R and decreasing r by the same amount.

Conventional Problems.

1. If the e.m.f. of a certain battery is 8 volts, and if the current obtained through an external resistance of 3.5 ohm is 2 amperes, the internal resistance of the battery is (1) 0.5 ohm, (2) 4 ohm, (3) 2.2 ohm, (4) 0.05 ohm.
2. An electrical appliance must not carry a current greater than 6 amperes. It has a resistance of 10 ohm and is to be used on a 110 volt circuit. The resistance which must be connected in series with the appliance is (1) 11 ohm, (2) 18⅓ ohm, (3) 5 ohm, (4) 8⅓ ohm.

Items Involving Practical Application

1. Home magazines and public power companies warn housewives not to "plug in" an excessive number of lamps or other household appliances at any one electrical outlet installation. The reason is:
   (1) If several appliances draw current from a common source, there is likely to be a deficiency in the amount of current flowing through each appliance and therefore inefficient operation of one or all of them.
   (2) Each additional appliance which is plugged into an outlet tends to decrease the total resistance of the circuit, thereby increasing the current in the line. This increase in current may result in a burned out fuse or damaged insulation.
   (3) As additional appliances are connected to an outlet, the voltage in the line increases. This increase in voltage may cause one of the appliances to burn out.
   (4) Each appliance has some electrical resistance, which when added to the resistance of those already connected to the outlet may reduce the current below that necessary for efficient operation of some one of the appliances.
2. Electrical equipment designed to operate on locally installed 32 volt farm power plants cannot be successfuly used, without modification, when connected to 110 volt municipal power lines. The reason is
   (1) The excess voltage of the municipal power lines causes overheating of the appliances with consequent damage to wiring and insulation.
   (2) The increased voltage results in excessive current in the wiring of appliances with consequent damage to wiring and insulation.
   (3) Since the voltage of the municipal lines is so much higher than that of the farm power plant, the current flowing through the appliances is too small for their efficient operation.

When the construction of the sixty test items relating to the ten principles of mechanics had been completed the informational items and conventional problem items were divided into two groups in such a manner that each group contained one informational item and one problem relating to each principle. The items within each group were then arranged by chance, assembled in test form, and designated respectively, as Mechanics Form A, Part I; and Mechanics Form B, Part I. The application items were divided and assembled in a similar manner into test forms of ten items each. These tests were designated, respectively, as Mechanics Form A, Part II; and Mechanics Form B, Part II. The same procedure was followed as test items were completed for the principles of Heat, Electricity, and Sound and Light. Thus, a total of eight informational tests of twenty items each, and eight application tests of ten items each were assembled and mimeographed.

The Administration of Tests

Early in the school year 1944-45, arrangements were made with the physics instructors in seven representative Nebraska high schools for the tests in each division of physics to be given at the close of the respective units of instruction. Later, through cooperation of the Physics Department of the University of Nebraska, the mechanics tests were also given to approximately eighty A. S. T. P. Reserves. Due to the fact that Nebraska has no uniform course of study in physics for all schools, the practice with respect to the time placement of the respective divisions of the subject differs in different schools. Thus, some schools teach the unit on light last and others finish the course with the unit of electricity. It was unfortunate for the study that three of the cooperating schools failed

to provide time for the administration of the tests on their closing unit. It was doubly unfortunate that, while two of these schools did not give the tests in light, a third school did not give the tests in electricity. There were, therefore, but four schools in which all tests were given. This condition required some deviation from the original plan for the treatment of data, as will be evident in following sections.

Tests were given in cooperating schools by the regular instructor. In each class, Form A and Form B tests were given to alternate pupils, respectively. With slight exceptions, two full periods of class time were allowed for the completion of the two tests covering each unit. While some difference in testing conditions undoubtedly existed, the fact that the effects of school differences in central tendency have been removed through statistical treatment of data should help to correct the effects of such irregularities. All tests were returned to the writer's office and were scored under his supervision. Tests were scored on the basis of the total number of correct responses with no deduction for guessing.

The total number of pupils who completed each pair of tests is as follows:

Mechanics Form A, Parts I and II	177 pupils
Mechanics Form B, Parts I and II	170 pupils
Heat Form A, Parts I and II	94 pupils
Heat Form B, Parts I and II	87 pupils
Electricity Form A, Parts I and II	81 pupils
Electricity Form B, Parts I and II	79 pupils
Light and Sound Form A, Parts I and II	61 pupils
Light and Sound Form B, Parts I and II	58 pupils

Refinement of Tests

No attempt was made to determine the validity of any of the tests employed in this study through correlation with a criterion test. In fact no acceptable criterion test is available for establishing the validity of the application tests. Whatever validity the tests may have is dependent upon the combined effects of the following:

1. Each test item was based upon a fundamental principle of physics an understanding of which has been found to be of high importance for general education.
2. It was assumed that the investigator possesses some degree of skill in formulating and evaluating test items which require exercise of the abilities he sought to measure and that a test made up of a number of items designed to measure the same ability would therefore, as a whole, have some degree of validity for measuring this ability.
3. It was further assumed that the elimination of items of low internal consistency within each separate test would make the test a more reliable measure of whatever ability or abilities it does measure.

For the purpose of determining internal consistency bi-serial correlation coefficients were computed between individual test items of each of the sixteen tests and the total distribution of scores made by all pupils taking this test. An index of difficulty, expressed as the per cent of pupils answering the item incorrectly, was also determined for each item of each test.

As was expected, the test items which were originally associated with any one principle differed considerably both with respect to indices of discrimination (bi-serial correlations) and indices of difficulty. While it might have been desirable to eliminate all items associated with a given principle whenever one of the items showed an unusually low index of discrimination, such a procedure would have resulted in shortening the total tests considerably and would in some cases have necessitated the elimination of items having relatively high indices of discrimination. On the other hand, elimination on an individual item basis meant that the scope of corresponding tests, in terms of principles involved, would not be quite identical. The latter alternative was selected as being less objectionable and the four items having the lowest indices of discrimination were eliminated from each of the eight informational tests while two items were discarded from each of the eight application tests. Thus a total of 48 individual items were discarded.

The range and the mean of the indices

of discrimination and of the indices of difficulty for items retained in each test appear in Table I.

Comparison of Results on Refined Tests

Following the completion of the item analysis as described in the preceding section, the test papers were sorted by schools and by subject matter division within each school. Corresponding forms of the tests on mechanics and on heat were combined for each individual pupil in each school and each composite test was rescored to secure a refined test score after items had been eliminated as previously described.

In case a pupil had not taken both the mechanics test and the corresponding test on heat his test papers were discarded from this section of the study. The same procedure was followed with corresponding forms of the test papers from each school to secure composite scores on the refined tests for mechanics, heat and electricity; mechanics, heat and light; and the total test, i.e., mechanics, heat, electricity, and light. Since one school wherein the tests on mechanics and heat were given did not give the tests on electricity and two others did not give the tests on light, the total number of schools from which composite refined test scores could be utilized varied from seven schools for mechanics and heat, to six for mechanics, heat and electricity, five for mechanics, heat, and light, and four for the total test.

A summary of the number of pupils from each cooperating school where refined test scores were utilized in each of the four composite divisions of physics is presented in Table II, and the distribution of scores made by these pupils in each of the four combinations of subject matter is indicated in Table III. When referring to these tables the reader should bear in mind (1) that Form A and Form B tests were administered simultaneously to pupils seated in alternate seats in the respective classrooms, and (2) that Part I tests were con-

TABLE I

RANGE AND MEAN OF INDICES OF DISCRIMINATION AND OF DIFFICULTY OF ITEMS RETAINED IN TESTS

	Index of Discrimination [a]		Index of Difficulty [b]	
Test	Range	Mean	Range	Mean
Mechanics Form A, Part I	.48–.83	.61	26%–82%	57%
Mechanics Form A, Part II	.40–.77	.58	15%–82%	39%
Mechanics Form B, Part I	.30–.71	.52	14%–83%	56%
Mechanics Form B, Part II	.41–.77	.56	24%–58%	41%
Heat Form A, Part I	.29–.87	.61	10%–71%	41%
Heat Form A, Part II	.54–.73	.64	9%–47%	23%
Heat Form B, Part I	.29–.83	.65	14%–68%	43%
Heat Form B, Part II	.60–.96	.80	14%–67%	32%
Electricity Form A, Part I	.40–.85	.62	18%–78%	57%
Electricity Form A, Part II	.35–.80	.54	24%–81%	53%
Electricity Form B, Part I	.30–.82	.56	27%–88%	55%
Electricity Form B, Part II	.30–.72	.57	27%–67%	44%
Sound and Light, Form A, Part I	.28–.85	.58	32%–78%	50%
Sound and Light, Form A, Part II	.24–.73	.53	4%–81%	43%
Sound and Light, Form B, Part I	.44–.96	.63	22%–92%	51%
Sound and Light, Form B, Part II	.48–.75	.61	5%–57%	30%

[a] It should be noted that the indices of discrimination appearing in this table were computed on the basis of scores on the total tests before items were eliminated. Indices computed by correlation of individual items with scores on the refined tests would of course be somewhat higher.

[b] Per cent of pupils answering the item incorrectly.

TABLE II

SCHOOLS FROM WHICH REFINED TEST SCORES WERE UTILIZED AND NUMBER OF PUPILS TESTED IN EACH

	Mechanics and Heat		Mechanics, Heat and Elect.		Mechanics, Heat and Light *		Mechanics, Heat, Light and Elect.	
	Form A	Form B	Form A	Form B	Form A	Form B	Form A	Form B
No. 1	25	17	18	14	10	9	16	9
No. 2	10	9	10	9				
No. 3	9	6			9	6		
No. 4	7	9	4	6	6	7	4	6
No. 5	11	10	11	10	11	10	11	10
No. 6	26	27	23	26				
No. 7	5	6	4	6	4	6	4	6
Total Pupils	93	84	70	71	40	38	35	31

* A number of items relating to sound were also included in these tests.

structed with a view to measuring abilities involved in the recall of information and in the solution of conventional type problems, while Part II tests were designed to measure the ability to apply principles in typical life situations.

TABLE III

DISTRIBUTION OF SCORES ON REFINED TESTS

Test	No. Pupils	No. Items	Range	Mean	Total Variance	S. D.
Mechanics and Heat						
Form A, Part I	93	32	7–28	17.19	20.46	4.52
Form A, Part II	93	16	5–16	11.54	9.59	3.10
Form B, Part I	84	32	8–32	17.97	22.59	4.75
Form B, Part II	84	16	3–15	10.02	7.36	2.71
Mechanics, Heat and Electricity						
Form A, Part I	70	48	14–38	26.27	40.32	6.35
Form A, Part II	70	24	7–22	16.37	12.21	3.49
Form B, Part I	71	48	13–47	26.38	48.35	6.95
Form B, Part II	71	24	5–23	15.76	14.76	3.84
Mechanics, Heat and Light						
Form A, Part I	40	48	13–38	25.12	37.16	6.10
Form A, Part II	40	24	8–22	15.95	10.56	3.25
Form B, Part I	38	48	14–46	26.58	46.30	6.80
Form B, Part II	38	24	6–22	15.82	13.83	3.72
Mechanics, Heat, Electricity and Light						
Form A, Part I	35	64	20–48	33.83	95.70	9.78
Form A, Part II	35	32	10–26	20.48	17.78	4.22
Form B, Part I	31	64	20–60	37.16	65.34	8.08
Form B, Part II	31	32	9–28	21.81	23.16	4.81

While parallel forms of the tests were in no case administered to the same group of pupils, the absence of significant differences between corresponding measures of central tendency and of variability in the two forms, as presented in Table III, is an indication of consistency both between the groups tested and between the parallel forms of each test.

Self-Correlations and Inter-Test Correlations Between Test Scores

It is assumed that each Part I test employed in this investigation represents a

measure of abilities closely associated with the recall of information and that each Part II test represents a measure of the ability to make practical application of an understanding of certain principles of physics. It is assumed, further, that a difference between these abilities, as measured in this study, is indicated by the extent to which the self correlation of any Part I test differs from the inter-test correlation be-

TABLE IV

ANALYSIS OF BETWEEN SCHOOLS AND WITHIN SCHOOLS VARIANCE

Test	Component of Total Variance	d.f.	Sum of Squares	Variance	F	Value of F * Required for Significance
Mechanics and Heat						
Form A, Part I	Between Schools	6	235.00	39.17	2.05	5%=2.21
	Within Schools	86	1646.90	19.15		1%=3.04
Form A, Part II	Between Schools	6	69.10	11.52	1.22	" "
	Within Schools	86	813.02	9.45		
Form B, Part I	Between Schools	6	527.75	87.96	5.03	5%=2.21
	Within Schools	77	1347.15	17.50		1%=3.04
Form B, Part II	Between Schools	6	96.63	16.10	2.54	" "
	Within Schools	77	487.32	6.33		
Mechanics, Heat, and Electricity						
Form A, Part I	Between Schools	5	401.24	80.25	2.13	5%=2.36
	Within Schools	64	2381.05	37.20		1%=3.31
Form A, Part II	Between Schools	5	54.47	10.89	0.88	" "
	Within Schools	64	788.33	12.32		
Form B, Part I	Between Schools	5	1527.94	305.95	10.71	5%=2.36
	Within Schools	65	1856.26	28.56		1%=3.31
Form B, Part II	Between Schools	5	325.38	65.08	5.98	" "
	Within Schools	65	707.55	10.89		
Mechanics, Heat, and Light						
Form A, Part I	Between Schools	4	416.57	104.14	3.54	5%=2.64
	Within Schools	35	1032.80	29.45		1%=3.91
Form A, Part II	Between Schools	4	58.26	14.56	1.44	" "
	Within Schools	35	353.64	10.10		
Form B, Part I	Between Schools	4	453.50	113.37	2.97	5%=2.66
	Within Schools	33	1259.76	38.17		1%=3.95
Form B, Part II	Between Schools	4	147.79	36.95	3.35	" "
	Within Schools	33	363.92	11.03		
Total Test						
Form A, Part I	Between Schools	3	1931.40	643.80	15.09	5%=2.91
	Within Schools	31	1322.43	42.66		1%=4.48
Form A, Part II	Between Schools	3	65.06	21.69	1.25	" "
	Within Schools	31	539.48	17.40		
Form B, Part I	Between Schools	3	651.70	217.23	4.48	5%=2.96
	Within Schools	27	1308.50	48.46		1%=4.60
Form B, Part II	Between Schools	3	259.33	86.44	5.36	" "
	Within Schools	27	435.51	16.13		

* Lindquist, *op. cit.*, pages 62–65.

tween this Part I test and the corresponding Part II test and vice versa.

The effect of school differences upon correlation coefficients obtained from samples made up of intact school groups is well known.[11]

In the present study the sampling of pupils consisted of intact groups of pupils who had been taught without any attempt to secure uniformity of content emphasis, teaching materials, or methods. In order to determine whether or not the effect of school differences should be eliminated when computing correlation coefficients the method of analysis of variance was employed.[12]

The results of this analysis are presented in Table IV.

When inspecting Table IV, it should be kept in mind that the schools in which the tests covering the four subject matter areas were given were not wholly identical and that therefore, consistency of variance for a given form or part of a test cannot be expected. The F values presented in the tables do, however, indicate that the ratio between the estimated *between schools* and *within schools* variances is in certain cases somewhat larger than chance would allow. In each of these cases, it follows that the intact school groups do not consist of random samples from the same population. While it was not the purpose of this study to investigate the reasons for these greater than chance differences in school means, the fact that some such differences do exist was considered sufficient justification for the utilization of a statistical technique through which the effect of school differences was eliminated and the *within schools* correlations computed. This technique, the analysis of co-variance, is also particularly suitable for use when samples are small.[13]

The *within schools* correlation between odd and even numbered items was computed for each of the eight Part I tests. Each of these correlations were then stepped up by Spearman-Brown formula[14] to secure a predicted self correlation for the entire test. In like manner a split-halves correlation was computed for each of the eight Part II tests and the resulting correlation stepped up to secure a predicted self-correlation for the entire test and also for a test twice the length of the entire test.

The *within schools* correlations between corresponding forms of the Part I and Part II tests were computed using scores obtained on the entire tests. In order to predict the inter-test correlation which would be obtained between each Part I test and a corresponding Part II test of equal length, a modification of a well known formula for finding the correlations between sums of measures if the correlation between measures is known, was utilized.[15] The modified formula follows:

$$r_{I,\,II}=\frac{nr_{I,\,2}}{\sqrt{n+(n^2-n)r_{2,\,2}}}$$

In this formula $r_{I,\,II}$ is the predicted correlation between scores on a Part I test and a Part II test of equal length, while $r_{I,\,2}$ is the obtained correlation between the entire Part I and Part II tests and $r_{2,\,2}$ is the reliability of the entire Part II test. The value n represents the number of Part II measures which must be added to the obtained Part II measure. In the present study the value of n is always 2 because of the fact that each Part I test is exactly twice as long as the corresponding Part II test.

In order to obtain a measure of the significance of the difference between the predicted self correlations and inter-test correlations a formula for computing t for the difference between correlated coefficients

[11] Lindquist, F. E., *Statistical Analysis in Educational Research*, Houghton, Mifflin Company, 1940, pages 219–228.

[12] *Ibid.*, pages 87–101.

[13] *Ibid.*, pages 180–188.

[14] Peters and Van Voorhis, *Statistical Procedures and Their Mathematical Bases*, McGraw-Hill Book Company, New York, 1940, page 194.

[15] *Ibid.*, page 193.

$(r_{1,2}-r_{1,3})$ as given by Lindquist[16] was employed. The formula follows:

$$t=\frac{(r_{12}-r_{13})\ \sqrt{n-3}\ \sqrt{1+r_{23}}}{\sqrt{2}\ \sqrt{1-r^2_{12}-r^2_{13}-r^2_{23}+2\,r_{12}\,r_{13}\,r_{23}}}$$

This test of significance is valid only for random samples. However, according to Lindquist, "a *within schools* correlation computed for a number of randomly selected schools may be treated as if it had been secured from a simple random sample of $n'-m+1$ cases (n' represents the total number of pupils and m represents the number of schools).[17] When computing values of t, therefore, the number of pupils (n in the formula) was determined by applying $(n'-m+1)$ and the degrees of freedom for t ($\sqrt{n-3}$ in the formula) was computed by use of this adjusted value of n'.

The self correlations and inter-test correlations for tests in each of the four combinations of subject matter are presented in the first seven columns of Table V and data relative to the significance of the differences are presented in the last four columns of the same table.

It is interesting to note in Table V the degree of agreement between predicted and obtained correlation coefficients for tests having an equal number of items. However, it should be noted when making such comparisons that items added to lengthen the tests always represented one or more different divisions of subject matter and that some schools included in the shorter tests were not included in the longer tests. For example, the predicted self correlation for the 32 item, Form A Part I, test in Mechanics and Heat is .66, while the obtained self correlation for the corresponding form of the entire test (32 items) is .72. The corresponding predicted and obtained coefficients for, Form B Part I are .68 and .62, respectively. For Form A Part II, these coefficients are .57 and .56, and for Form B Part II, they are .63 and .61, respectively. The greater agreement between the self correlation coefficients for the Part II tests may be an indication that the ability measured by these tests is less influenced by the area of subject matter than are the abilities measured by Part I tests.

The values of t shown in Table V indicate that in eight of the sixteen comparisons the differences are significant at the 1% level. The remaining eight comparisons show differences which vary in significance from the 2% to the 20% level. The differences are in general more significant for Form A than for Form B tests, the number of differences which are significant at the 1% level being 6 for Form A to 2 for Form B.

While these data do not justify the conclusion that the abilities measured are distinctly different, the weight of evidence gives support to the conclusions of earlier studies that the ability to recall and the ability to apply are different abilities.

The absence of a perfect relation between the abilities measured in this investigation is again evident when the inter-test coefficients of correlation are corrected for attenation. This information is presented in Table VI. Here again, it is evident that the differences are more pronounced when comparisons are made on the basis of the Form A tests. There is an indication also that the Form A tests were more consistent than the Form B tests.

Relations Between Test Scores and I.Q.

In order to be able to determine the extent to which intelligence is related to each of the abilities measured in this investigation an intelligence score for each pupil who responded to the tests was secured from participating schools. While these scores were in some instances obtained on different intelligence tests in the different schools, the school differences and therefore test differences were at least

[16] Lindquist, *op. cit.*, page 218.
[17] *Ibid.*, page 22.

TABLE V
COEFFICIENTS OF CORRELATION (WITHIN SCHOOLS)[a]

Test Sections	8 items	12 items	16 items	24 items	32 items	48 items	64 items	$r_{I,I}-r_{I,II}$	$r_{II,II}-r_{II,I}$	T	Level of Significance[b]
Mechanics and Heat											
Form A-I (self)			.49	→	.66			.20		2.46	2%
				.41							
Form A-II (self)	.40		.57	←	.73				.27	3.63	1%
Form A-I–A-II					.46						
Form B-I (self)			.51	→	.68			.14		1.83	10%
				.49							
Form B-II (self)	.46		.63	←	.77				.23	3.41	1%
Form B-I–B-II					.54						
Mechanics, Heat and Electricity											
Form A-I (self)				.62	→	.77		.27		3.47	1%
					.44						
Form A-II (self)		.40		.57	←	.73			.23	2.78	1%
Form A-I–A-II						.50					
Form B-I (self)				.57	→	.73		.09		1.33	20%
					.57						
Form B-II (self)		.41		.58	←	.74			.10	1.51	20%
Form B-I–B-II						.64					
Mechanics, Heat and Light											
Form A-I (self)				.50	→	.67		.22		1.81	10%
					.40						
Form A-II (self)		.40		.57	←	.73			.28	3.38	1%
Form A-I–A-II						.45					
Form B-I (self)				.74	→	.85		.15		2.24	5%
					.64						
Form B-II (self)		.50		.67	←	.80			.10	1.32	20%
Form B-I–B-II						.70					
Mechanics, Heat, Light, Electricity											
Form A-I (self)					.72	→	.84	.35		3.75	1%
						.47					
Form A-II (self)			.56		.72	←	.84		.35	3.75	1%
Form A-I–A-II							.51				
Form B-I (self)					.62	→	.77	.15		1.89	10%
						.58					
Form B-II (self)			.61		.76	←	.87		.25	3.15	1%
Form B-I–B-II							.62				

[a] This Table should be interpreted as follows: The correlation between odd and even items of the Form A, Part I test on Mechanics and Heat is .49, stepped up by the Spearman Brown formula it is .66. The correlation between odd and even items of the Form A, Part II test on Mechanics and Heat is .40, stepped up to twice length by the Spearman Brown formula it is .57, and to four times length it is .73 The obtained inter-test correlation between the 32 item Part I test and the 16 item Part II test is .41. The predicted correlation between the 32 item Part I test and a 32 item Part II test is .46. The difference between $r_{I,I}$ and $r_{I,II}$ is $.66 - .46 = .20$ ($t = 2.46$) and the difference between $r_{II,II}$ and $r_{II,I}$ is $.73 - .46 = .27$ ($t = 3.63$).

[b] Lindquist, op. cit., page 53.

TABLE VI

CORRELATION COEFFICIENTS CORRECTED FOR ATTENUATION *

Test	$r_{1.1}$	$r_{2.2}$	$r_{1.2}$	$r_{1.2}$ (Corrected)
Mechanics and Heat. Form A.	.66	.57	.41	.67
Mechanics and Heat. Form B.	.68	.63	.49	.75
Mechanics, Heat and Electricity. Form A.	.77	.57	.44	.67
Mechanics, Heat and Electricity. Form B.	.73	.58	.57	.88
Mechanics, Heat and Light. Form A.	.67	.57	.40	.66
Mechanics, Heat and Light. Form B.	.85	.67	.64	.85
Mechanics, Heat, Electricity and Light. Form A.	.84	.72	.47	.60
Mechanics, Heat, Electricity and Light. Form B.	.77	.76	.58	.76

* The coefficient corrected for attenuation represents the predicted coefficient of correlation which would be obtained between two perfectly reliable measures of whatever abilities the tests actually do measure. If the tests measure the same thing the corrected coefficients should be 1.00.

partially equalized by computing the *within schools* correlation coefficients between intelligence and each of the abilities measured by the respective tests employed in this study. The results of these computations showing the relation of intelligence scores and scores on tests covering Mechanics, Heat and Electricity are presented in Table VII. The obtained values of t show clearly that intelligence as measured by conventional intelligence tests is not identical with either of the abilities measured in this investigation.

Relation Between Test Scores and Final Grades

There remains the problem of determining the relationship between course grades assigned by classroom teachers and each of the abilities investigated. Final course grades were secured from each cooperating teacher. If these grades were reported in any form other than as a percentage grade, the transformation to a percentage grade was made in accordance with the instructions given by the cooperating school. *Within Schools* correlation coefficients were computed between grades and scores on each of the tests on Mechanics, Heat and Electricity. The results of these computations are shown in Table VIII.

The data presented in Table VIII indicate that final course grades are not an adequate measure either of the ability to recall information as measured by Part I tests or of the ability to apply principles as measured by Part II tests.

The rather close agreement of the coefficients of correlation between intelligence and the Part I and Part II tests (Table VII) and between grades and these same tests (Table VIII), suggests the calculation of the correlation between grades and intelligence. The *within schools* coefficient of correlation between grades and intelligence was found to be .49.

CONCLUSIONS

1. The weight of evidence resulting from this investigation supports the conclusion that abilities associated with the recall of information relative to principles of physics and with the solution of "formula" type problems, are not identical with abilities involved in applying these same principles in the solution of practical problematic situations which are typical of out-of-school experience.

2. The investigation reveals evidence that the ability to recall information relating to principles of physics and the ability to make practical application of an understanding of the principles are related to intelligence to approximately the same degree. However, the I. Q. as measured by standard intelligence tests is not a valid measure of either of the abilities.

3. The results of the investigation indicate that the final grades of pupils in high school physics are not a valid measure

TABLE VII

CORRELATION OF TEST SCORES WITH INTELLIGENCE (WITHIN SCHOOLS)

Test	N	$r_{I,I}$	$r_{I,i}$	$r_{II,II}$	$r_{II,i}$	$r_{I,I}-r_{I,i}$	$r_{II,II}-r_{II,i}$	t[a]	Significance[b]
Mechanics, Heat, Electricity									
Form A, Part I	65	.77	.52			.25		3.17	Significant at 1% level
Form A, Part II	65			.73	.45		.28	3.07	" " " "
Form B, Part I	68	.73	.50			.23		2.74	" " " "
Form B, Part II	68			.74	.48		.26	3.09	" " " "

[a] Lindquist, *op. cit.*, page 218
[b] *Ibid.*, page 53.

TABLE VIII

CORRELATION OF TEST SCORES WITH GRADES (WITHIN SCHOOLS)

Test	N	$r_{I,I}$	$r_{I,g}$	$r_{II,II}$	$r_{II,g}$	$r_{I,I}-r_{I,g}$	$r_{II,II}-r_{II,i}$	t[a]	Significance[b]
Mechanics, Heat, Electricity									
Form A, Part I	65	.77	.53			.24		3.17	Significant at 1% level
Form A, Part II	65			.73	.38		.35	3.71	" " " "
Form B, Part I	68	.73	.53			.20		2.52	" " 2% level
Form B, Part II	68			.74	.51		.23	2.86	" " 1% level

[a] Lindquist, *op. cit.*, page 218
[b] *Ibid.*, page 53.

either of the ability to recall information relating to principles of physics or of the ability to make practical application of principles as these abilities are measured in this study.

IMPLICATIONS FOR FURTHER RESEARCH

It is possible that certain teaching techniques might be perfected which would result in an improvement of the ability of high school physics pupils to make practical applications of the principles of physics. Before controlled research relating to this problem can be undertaken, it will be necessary to have available a test which adequately covers the more important principles of physics and which represents a valid and reliable measure of the ability to make practical application of an understanding of these principles.

As a result of the present investigation, the writer has available a total of sixty-four test items, each designed to measure the ability to make practical application of one or more of the more important principles of physics. The items have been tested through actual use and indices of discrimination and difficulty are available for each. These test items should furnish the raw material from which a satisfactory evaluative instrument can be constructed for future use in research on the relative values of teaching techniques designed to improve the ability to make practical application of the principles of physics. It is the opinion of the writer that research which will point the way toward securing greater transfer as a result of instruction in high school physics is much needed.

A DETERMINATION OF THE PRINCIPLES OF ENTOMOLOGY OF SIGNIFICANCE IN GENERAL EDUCATION. II*

GEORGE J. BERGMAN

IN Part I of this article, which appeared in a previous issue,† an account was given of the manner in which the 52 principles of entomology and the 45 principles of biology were determined and matched up. Part II will describe the results of checking the principles of entomology against criteria of general education.

DETERMINATION OF THE CRITERIA OF GENERAL EDUCATION

A criterion is a test, principle, or standard by which something is judged. In the present study, it was considered necessary to determine and list those criteria which are basic to the inclusion of certain subject matter in general education programs.

A careful study of the literature disclosed that these criteria were actually aims and objectives of general education. Many common elements were found among the various books and articles dealing with general education.

The Committee on a design for General Education of the American Council on Education (1) has drawn up a comprehensive list of 10 objectives of general education for members of the armed forces. Briefly, it includes the following considerations relative to the student:

1. Improving and maintaining his own health and that of others.
2. Writing and speaking his own language.
3. Sound emotional and social adjustments.
4. Satisfactory family and marital adjustments.
5. Dealing with social, economic, and political problems of American life, and international relations.

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*Based on a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the School of Education of New York University, October, 1946.

†February, 1947.

6. Understanding of natural phenomena; use of the scientific method in the solution of problems.
7. Self-expression in literature.
8. Self-expression in music, the arts, and crafts; understanding and appreciation of art and music.
9. The meaning and value of life.
10. Choice of a vocation.

Also stressed are the ability to think rigorously and critically, and the knowledge, skills, abilities, and attitudes involved in critical and reflective thinking.

The Committee on the Function of Science in General Education of the Progressive Education Association (2) has stated the importance of meeting the needs of adolescents in the following areas: personal living, personal-social relationships, social-civic relationships, and economic relationships, together with the encouragement of reflective thinking. These areas of significant human experience have also been emphasized by Bigelow (3) in his discussion of the materials for general education.

The General Education Committee of the North Central Association of Colleges and Secondary Schools (4) has added as objectives the understanding of basic scientific concepts and the application of principles of science to problems arising in daily living. The Harvard Committee on the Objectives of General Education in a Free Society (5) has attached considerable importance to knowledge which is functional.

Peik (6) views the outcomes of general education as comprising the following: knowledge (information and generalizations), habits, skills, ideals, attitudes, appreciations, motivations, participation in life, and critical and creative thinking. Pothoff (7), Scroggs (8), and Judd (9) have contributed objectives similar to those given above.

Thayer (10) reports that Goucher College for Women in Baltimore, Maryland, has built its curriculum about eight objectives of a general education which relate directly to the life activities of women. This has been done also by Stephens College in Columbia, Missouri (11).

By careful analysis of each article and book consulted it was possible to divide the criteria of general education into two categories-general criteria and specific criteria. General criteria are broad, comprehensive, and inclusive, while specific criteria relate to specific subject matter topics and specific outcomes of general education. The resulting 25 criteria are given below:

CRITERIA OF GENERAL EDUCATION

GENERAL CRITERIA. *Knowledge which:*

1. Has cultural value.
2. Has practical application.
3. Has functional value.
4. Is useful in daily life.
5. Contributes to reflective or critical thinking.
6. Contributes to adjustment to one's environment.

Education which contributes to:

7. Acquisition of skills and abilities.
8. Development of interests.
9. Development of attitudes.
10. Development of appreciations.

SPECIFIC CRITERIA. *Knowledge related to:*

11. Physical and mental health.
12. Understanding and control of natural environment.
13. Understanding of basic scientific concepts.
14. Application of scientific method.
15. Economic welfare and security.
16. Economic, social, and political problems of American life.
17. Choice of a vocation.
18. Development of a philosophy of life.
19. Parenthood and family relationships.
20. Appreciation of, and self-expression in, art and music.
21. Social and civic relationships.
22. Personal problems and personality development.
23. Oral and written communication.
24. Responsible citizenship.
25. Appreciation of literature.

These criteria or objectives are basic elements in American education, and are goals to be achieved by students and teachers alike.

APPLICATION OF CRITERIA OF GENERAL EDUCATION TO PRINCIPLES OF ENTOMOLOGY

In order to evaluate the significance of the 52 principles of entomology for general

education, questionnaires were sent to 94 specialists in 4 distinct groups. These included 30 entomologists, 20 biologists teaching in colleges or universities, 21 heads or chairmen of high school departments of biology, and 23 science educators. All of the entomologists and college biologists were chosen from the sixth edition of *American Men of Science* (12). All of the science educators are members of the National Association for Research in Science Teaching, while the high school biology departmental chairmen were judged to be outstanding on the basis of their abilities and publications.

A mimeographed questionnaire was sent to each specialist, and was composed of (a) an introductory page explaining the nature and purpose of the study, (b) six pages upon which were listed the 52 principles of entomology, and (c) the 25 criteria of general education.

The following directions appeared at the top of the first page of principles:

> **Please check each principle against the attached criteria of general education. On the line to the left of each principle, write the number or numbers of the criterion or criteria which, in your opinion, are met by the principle, either slightly or definitely. Please encircle the number of a criterion which you think is met by a particular principle to a great extent.**

Replies were received from 52 persons, 37 of whom had filled out the questionnaire. Those who replied fell into the following categories: 14 entomologists, 6 college biologists, 10 chairmen of high school departments of biology, and 7 science educators.

Determination of Basic Data

The results were first tabulated on the basis of principles. For the sake of brevity, the criteria of general education were listed by their assigned numbers, from 1 to 25, as given above.

A single grand total for each principle and for each criterion under each principle was obtained by adding the data for the 4 groups. The criteria were then ranked in descending order in accordance with their frequencies. The data for the principle designated as POSITION IN THE ANIMAL KINGDOM is given below as an example, wherein:

Cr equals the numbers of the criteria of general education ranked in order of their frequencies.

T equals the combined total number of entomologists, college biologists, high school biologists, and science educators who selected the criteria next to which the totals are written.

O equals the number of encircled figures included under *T*.

%N equals the percentage of men (to the nearest per cent) who replied to each item, obtained by dividing each number under *T* by 37 (total number of questionnaires).

%O equals the percentages of encircled items (to the nearest per cent) under each criterion, obtained by dividing *O* by *T*.

POSITION IN THE ANIMAL KINGDOM

Rank	*Cr*	*T*	*O*	*%N*	*%O*
1.0	1	30	10	81	33
2.0	13	24	11	65	46
3.0	8	18	7	49	39
4.0	12	16	8	43	50
5.0	10	15	1	41	7
6.0	5	13	3	35	23
7.0	2	12	2	32	17
8.0	15	7	4	19	57
9.0	6	7	2	19	29
10.0	3	7	1	19	14
11.5	4	5	1	14	20
11.5	14	5	1	14	20
13.0	25	5	0	14	0
14.0	7	4	1	11	25
16.0	9	4	0	11	0
16.0	11	4	0	11	0
16.0	16	4	0	11	0
18.0	17	3	0	8	0
19.5	18	2	0	5	0
19.5	23	2	0	5	0
23.0	19	1	0	3	0
23.0	20	1	0	3	0
23.0	21	1	0	3	0
23.0	22	1	0	3	0
23.0	24	1	0	3	0

Based on the data in the *%N* columns, frequency tabulations were made of en-

tomological principles for which criteria of general education were chosen by 50 to 74 per cent and 75 to 100 per cent of the specialists, individually by groups, and combined. Those principles for which criteria were entered by 75 to 100 per cent of the specialists are considered to be significant in general education, while principles for which criteria were entered by 50 to 74 per cent of the specialists would also seem to have some significance in general education.

Three groups of percentages were also drawn up for each catagory of specialists, as well as for all groups together: one in which 25 to 49 per cent of the criteria in each rank was encircled, another in which 50 to 74 per cent of the criteria had been encircled, and a third qroup with 75 to 100 per cent of the criteria in each rank encircled.

Two tables were drawn up which summarized the data concerning the ranking of criteria and their respective principles. One table indicated the number of principles of entomology under each criterion, according to ranks from 1.0 through 25.0, including mid-points between successive ranks. The other table gave the number of times each criterion appeared among the 37 questionnaries, also based on combined results for all the specialists. Two significant lists of criteria of general education appearing most frequently in their relative order of importance were drawn up from the data given in these tables.

Significant results for comparative purposes were obtained by noting those criteria of general education which were among the first five listed in the combined tabulations for all groups. An extensive table was drawn up giving the ranked criteria for each of the 52 principles of entomology, with the results for entomologists, college biologists, high school biologists, and science educators tabulated under each principle.

The most significant principles of entomology were those for which criteria were chosen by at least 75 per cent of the men in each group. For some principles only a single criterion was noted by 75 to 100 per cent of a group, while for other principles as many as 4 or 5 criteria were thus chosen. For each group of specialists the preferred principles were arranged in descending order, based on the number of criteria attaining the 75 to 100 per cent range, and on the numerical order of the percentages.

Four separate lists of criteria of general education in order of their importance as regards the principles of entomology were drawn up for the entomologists, college biologists, high school chairmen of departments of biology, and science educators. Based on these lists, on the frequency of occurrence and on the relative ranks of the criteria, a single, all-inclusive list of the criteria of general education was drawn up in the order of their importance in relation to the principles of entomology. This list follows:

1. Has cultural value.
2. Understanding of basic scientific concepts.
3. Understanding and control of natural environment.
4. Development of interests.
5. Has practical application.
6. Contributes to reflective or critical thinking.
7. Economic welfare and security.
8. Has functional value.
9. Development of appreciations.
10. Contributes to adjustment to one's environment.
11. Application of scientific method.
12. Is useful in daily life.
13. Acquisition of skills and abilities.
14. Development of attitudes.
15. Physical and mental health.
16. Economic, social, and political problems of American life.
17. Choice of a vocation.
18. Appreciation of literature.
19. Development of a philosophy of life.
20. Oral and written communication.
21. Responsible citizenship.
22. Parenthood and family relationships.
23. Social and civic relationships.
24. Personal problems and personality development.
25. Appreciation of, and self-expression in, art and music.

By careful analysis of the frequency with which various principles appeared

among the four groups, the frequency of principles whose criteria were selected and encircled by 75 to 100 per cent of the specialists, and those whose criteria were selected and encircled by 50 to 74 per cent of the specialists, a list of the principles of entomology was drawn up in the order of their relative significance for general education. This list is given below. Each principle of entomology appears immediately below its corresponding biological principle, to which it is subordinate.

In the following list, a "B" refers to a principle of biology, while an "E" indicates a principle of entomology. A minor principle is indicated by an asterisk(*). A. major principle is not preceded by an asterisk. It is to be noted that in some cases a particular principle of biology has several principles of entomology subordinate to it. In such a case, the principle of biology has been repeated, so as to correspond to its subordinate entomological principles which fall into different ranks. The principles of entomology are numbered from 1 through 52 to indicate their relative significance. The principles of biology are numbered from 1 through 45. Where it has been necessary to repeat a biological principle, the repeated principle bears the same number as the original.

B(1) Each communicable disease is caused by a specific microorganism, infection being possible only when a virulent, infecting microorganism enters a receptive host in sufficient numbers by an appropriate avenue.

E(1) Insects are injurious or harmful to man by causing great economic loss; they destroy or damage many kinds of growing crops and other valuable plants; they spread diseases of plants, man, and domestic animals by transmitting to them pathogenic bacteria, protozoa, fungi, roundworms, and viruses; they destroy or depreciate the value of stored food and other products and possessions.

B(2) Living things are dependent upon one another for their existence.

E(2) Insects are beneficial and useful to man; they produce useful substances or articles of economic importance, such as silk, beeswax, lac, honey, cochineal pigment, cantharidin, and galls for making tannic acid, permanent inks, and dyes; they aid in the production of fruit, vegetables, and seeds by pollinating the blossoms; they serve as food for certain plants, fish, birds, and many other animals including man; they destroy other insects which are injurious, either as parasites or predators; they are used extensively in the study of genetics; they are useful in medicine (blister beetles, fly maggots, honeybee stings); and their shapes and forms are widely used as ornaments.

B(1) Each communicable disease is caused by a specific microorganism, infection being possible only when a virulent, infecting microorganism enters a receptive host in sufficient numbers by an appropriate avenue.

E(3) Many insects harm man and domestic animals by causing decreased working efficiency and productivity, loss of vitality, disease, illness, or death, in the following ways: they pierce the skin and suck blood; they inject pathogenic microorganisms into the blood; they bite and sting, causing severe skin irritations; they carry pathogenic microorganisms on their wings and on the hairs of their bodies and legs, and deposit them in food by contact; they lay their eggs in the hair, skin, and organs of the body, and the larvae which hatch feed on the living tissues, thus causing ulcerous conditions.

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*B(3) Most species of organisms are subject to check or control by natural biological enemies.

E(4) Insects with chewing mouth parts can be controlled with *stomach poisons* which are either sprayed or dusted on the parts of the plant upon which the insects feed, or used in the form of a poison-bait mixture containing a substance which is attractive to the insects; those having piercing-sucking mouth parts can be controlled by contact poisons which, when applied directly to the body of the insect in the form of a dust or spray, enter the tracheae and kill by producing a chemical action on the vital tissues, or by clogging the breathing tubes; however, contact poisons may be used to kill any insect regardless of the type of mouth parts, providing it is hit by the dust or spray; gaseous poisons, or *fumigants*, are also used against insects regardless of mouth parts, but they are generally applied in tight enclosures.

B(4) Protective adaptations aid survival.

E(5) In the process of evolution, insects have acquired various kinds of protective adaptations: tough, resistant exoskeletons; stings, poison hairs and spines; repulsive odors; corrosive and defensive fluids; cocoons, puparia, and nests; small and inconspicuous sizes; frightful appearances; forms and colors resembling parts of plants; color mimicry; repulsive tastes; warning colorations; swift and varied forms of locomotion; protective body secretions; habitations in soil, plants, and bodies of animals; and nocturnal habits.

B(5) Many organisms hibernate or migrate in order to survive unfavorable atmospheric changes or food shortages.

E(6) Insects migrate, i. e., move to a new location, when the local food supply has become exhausted, or when environmental conditions have become unfavorable; some insects migrate considerable distances, but others do not migrate very far, feed slowly, and feed for a comparatively long period of time on definite species of plants.

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*B(6) New kinds and varieties of living things are produced by changes or variations in the germ cells.

E(7) Under ordinary conditions, insects are usually much more abundant on one particular host than on any others, and, if they feed on only one species of plant or animal, some varieties of the host will be preferred to others; many destructive insects are controlled by the use of special varieties or strains of animals and cultivated plants which are resistant or tolerant to their attacks.

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*B(3) Most species of organisms are subject to check or control by natural biological enemies.

E(8) Many insects are held in check by natural biological enemies, such as predatory and parasitic insects; predatory vertebrates; predatory spiders, scorpions, and mites; nematode (roundworm) parasites; parasitic fungi; and bacterial, virus, and protozoan diseases.

B(7) Every individual is composed of distinct and independent hereditary characters which are transmitted from parents to offspring by hereditary factors called *genes* (contained in chromosomes of the nuclei of cells), which can separate and recombine in such ways that the characters they represent appear to act as separate units.

E(9) The characteristics of insects, as those of other organisms, are formed by the actions of genes in the chromosomes of the nuclei of cells; in insects, special actions of genes determine sex, pigmentation, symmetrical pattern of wings, and the rate of growth during development.

B(8) There is great variation in the structural organization of living things, but there are also fundamental natural similarities and close relationships among organisms.

E(10) An insect is a representative of the animal kingdom belonging to the group of *Invertebrates* (animals without backbones), phylum *Arthropoda* (animals with a segmented body covered by a chitinous exoskeleton, jointed appendages, bilateral symmetry, ventral nervous system, dorsal heart), class *Insecta* or *Hexapoda* (one or two pairs of wings in the adult stage, three pairs of legs, body divided into head, thorax, and abdomen); on the basis of characters such as the presence or absence of wings and their main features, mouth parts, metamorphosis, and structure of the antennae and tarsi, the *Insecta* has been further subdivided into orders, then into suborders, families, genera, species, and varieties.

B(9) A balance of nature exists in which each form is so adjusted to other plants and animals and to physical surroundings, that it maintains itself at a fairly constant level.

E(11) Insects comprise about 75 per cent (640,000 described species) of all known species of animals, and carry out a great variety of activities, therefore they exert a profound effect upon almost all forms of plant and animal life.

B(10) Certain associations of plants and animals, such as community or social life, parasitism, and other forms of symbiosis, are the result of a competitive and cooperative struggle for survival.

E(12) The social life of certain insects has resulted from gradual family expansion through increased reproduction, leading to the development of insect castes and polymorphism (many forms), in which queens (frequently greatly developed) specialize in the production of eggs, workers (females with imperfectly developed reproductive organs) seek and provide food and accomodations for the young, males function mostly for reproduction, and soldiers have adaptations for defense.

B(11) Certain optimum conditions of temperature, moisture, light, and other factors are essential to the normal existence of most living things.

E(13) Each insect species, in each of its life cycle stages, can perform its normal functions within a wide range of temperature, but development is speeded up by high temperatures and slowed down by low; resistance to lethal temperatures depends on the size of the insect, its food reserves, humidity, and on the temperature of the air immediately surrounding the insect; each species becomes inactive or stops developing at a different low temperature, most insects being killed when their tissues freeze, but the effect of any temperature depends on the conditions to which the insects has been exposed.

B(12) All present living things are the changed or modified descendants of animals and plants which lived at an earlier time.

E(14) Present-day insects demonstrate highly developed and specialized structures and adaptations, as well as primitive, vestigial, and degenerate structures, the results of varied trends of evolution.

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*B(13) Most organisms undergo changes in structure and form in order to reach the adult stage.

E(15) Insects undergo a more or less marked change of form (metamorphosis) in order to reach the adult stage; some insects undergo an *incomplete* metamorphosis, during which the young (nymph) has the general structure and form of the adult, and has compound eyes, but develops wings and sexual organs gradually; other insects demonstrate a *complete* metamorphosis, in which the young (larva) has lateral simple eyes, internal wing buds, and a very rudimentary reproductive system, and changes into a quiescent, non-feeding pupa which

in turn changes into the adult; primitive, wingless insects become sexually mature at some indefinite point, but may continue molting, and thus attain the adult stage without a metamorphosis.

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*B(14) A parasite harms its host by actively attacking the tissues, by liberating poisons or toxins within the body of the host, by competing with the host for food, or by preventing reproduction of the host.

*E(16) Individuals from all the major orders of insects feed upon other insects; an insect which parasitizes other insects is free-living in the adult stage, but in its larval stage develops within or upon a particular host which eventually dies; a predatory insect is free-living in both adult and larval stages, and kills many individuals by direct attack.

B(15) Living things are not distributed uniformly or at random over the surface of the earth, but are found in definite zones and local regions, in which each species is adapted in its own way to the particular conditions of its particular environment.

E(17) Insects spread out most rapidly in the zones in which they originate, and in the direction of least resistance, being dispersed by flight, pedal actions, wind, water, plant and animal hosts and carriers, and by public or commercial means of transportation, but natural barriers and climatic conditions tend to prevent wide distribution of particular species.

B(16) Plants and animals are directly or indirectly dependent upon the soil.

E(18) Many species of insects are directly or indirectly dependent on the soil, by undergoing part of their development in it, seeking shelter in it, or by feeding on the plants nourished by it.

B(17) From the lower to the higher organisms, there occurs an increase in the complexity of structure, with a corresponding increase in the division of labor.

E(19) The body of an insect is divided into segments which permit greater freedom of movement and activity, and, as a result of specialization, specific functions are performed by the three parts of the body—the *head* (bearing the mouth parts and special sense organs), the *thorax* (bearing the organs of locomotion in the adult), and the *abdomen* (concerned with reproduction and general metabolic processes).

B(18) Food is necessary to the continued existence of all living things, in order to supply fuels (fats and carbohydrates) as sources of energy, materials (proteins) for growth and repair of tissues, and substances (minerals, vitamins, water) for regulating body processes.

*B(19) The manner in which an organism feeds depends on its adaptations for obtaining food.

E(20) Many insects *pierce* tissue *and suck* blood or plant fluids with a slender beak, of which the outer sheath, or labium, is often jointed or segmented; the mandibles, maxillae, and labrum, are frequently modified to conform to the particular feeding activities of the insect.

E(21) Insects which tear off and chew plant or animal tissue have *chewing* mouth parts, composed of the *labrum* which helps pull food into the mouth; two *mandibles* which cut and tear off food; two *maxillae* which bear organs of touch, taste and smell, and also hold and rake food back to the mandibles; a large, tongue-like ventral lobe called the *hypopharynx;* and a composite *labium* which is also sensory in function.

B(20) All living things arise from preceding living things each reproducing its kind; through the process of reproduction new individuals are produced, either asexually by division of protoplasm, or sexually whereby a male cell from one parent unites with the female cell from the other parent to produce young.

E(22) Reproduction in most insects is bisexual; an egg cell will develop only after fusion with a spermatozoal cell from the male insect. The essential parts of the adult female reproductive system consist of a pair of cylindrical, tapering *ovaries,* each composed of separate egg tubes or ovarioles; two separate *oviducts* which fuse into a median oviduct to open posteriorly at the *gonopore;* usually a *spermatheca* for receiving and storing spermatozoa; a pair of *accessory glands* which secrete the egg-covering or cement for attaching eggs; and a copulatory pouch or *vagina.* The male reproductive system includes a pair of *testes,* each composed of a variable number of follicles; a pair of seminal ducts or *vasa deferentia* which may be dilated to form *seminal vesicles* or sperm reservoirs; and an *ejaculatory duct* which leads to the copulatory organ.

B(9) A balance of nature exists in which each form is so adjusted to all other plants and animals and to physical surroundings, that it maintains itself at a fairly constant level.

E(23) The abundance of a particular species, and of insects in general, depends on their ability to survive and multiply in spite of environmental forces which affect them, including *physical factors,* consisting of temperature, humidity, light, nutrition, wind movement, and topography; and *biotic* factors, such as competitors, parasites, predators, pathogenic microorganisms, and mechanical and chemical control.

B(21) Organisms maintain their body form by consistency of the tissues, internal pressure of body fluids, an external membrane, or by rigid supporting structures.

E(24) Every insect is covered externally with a *cuticula* composed of a non-chitinous, acid-resisting surface layer (epicuticula) which protects the

insect against excessive humidity, dryness, and disease organisms; and two principle layers (endocuticula and exocuticula) containing *chitin*, a colorless, nitrogenous, porous substance which resists ordinary corrosive chemicals; between the joints the exocuticula becomes *sclerotized*, forming hard body-wall plates or sclerites which constitute the exoskeleton of the insect.

B(11) Certain optimum conditions of temperature, moisture, light, and other factors, are essential to the normal existence of most living things.

E(25) The length of the life cycle of insects is usually regular, and under normal, regular environmental conditions, young insects hatch from their eggs with a fair degree of certainty during particular months of the year.

E(26) Many (heterodynamic) insects, especially those which pass the winter in the egg stage, undergo a spontaneous arrest of development (diapause) regardless of environmental conditions, this state also occurring in the larvae, pupa, and adult, but varying in different species and among individuals of a single species; in many other (homodynamic) insects, successive generations are produced under favorable conditions, growth being arrested only by unfavorable conditions such as cold, drought, or starvation.

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*B(22) All gradations of intimate association (symbiosis) occur between organisms of different species, from those which are mutually beneficial to the organisms concerned (mutualism), to those in which one species secures all the advantage at the expense of the other (parasitism).

*E(27) Among insects, mutually beneficial symbiotic relationships or intimate associations result in special protection for some very destructive forms.

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*B(23) Every kind of living thing has developed a particular manner of reproduction which enables it to compete successfully with other organisms in the struggle for survival.

*E(28) In addition to normal reproduction, whereby fertilized eggs undergo their entire development outside the body of the female (oviparity), certain variations occur in the reproduction of insects; some insects develop from unfertilized eggs (parthenogenesis); eggs may be retained within the female until development is well advanced, so that hatching occurs immediately upon deposition, or the eggs may hatch within the female and active larvae or nymphs are brought forth (viviparity); a single egg may divide asexually and produce many embryos (polyembryony); and reproduction may take place in the larval or pupal stages (paedogenesis).

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*B(24) Many organisms provide protection for eggs, seeds, or other initial stages of development.

*E(29) Some insects demonstrate parental care of eggs, but usually insect eggs hatch without further care after being laid in places where the young may find suitable food and shelter; eggs may be buried in the ground, hidden in a deep crevice, inserted into plant tissues, laid on or near host plants, laid beneath a cottony web or covering, surrounded with gelatin and laid in water, injected into animal hosts, fastened to hair or feathers, enclosed in a horny case or capsule, laid on, in, or near other insect eggs and larvae, or just dropped at random.

B(25) The chemical changes which constitute metabolism take place continuously in the protoplasm of the cells; protoplasm is either built up from simple substances through chemical processes (metabolism), or else the complex substances making up protoplasm are broken down into simpler forms (katabolism).

E(30) Within a given species, at a given temperature, the rate of metabolism shows a definite relation to the size of the insect, the metabolic rate decreasing as the insect increases in size; in insects having a high rate of metabolism, there is rapid formation of protoplasm, and a rapid release of energy.

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*B(26) All individuals of a particular species are essentially alike, except for inconstant, individual differences.

*E(31) Insects of a particular species and sex look alike, usually behave in a similar manner, usually feed on the same kinds of foods, and are controlled in exactly the same way.

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*B(27) Growth and repair are fundamental activities of all protoplasm.

E(32) In insects, all increase in size takes place in the larval and nymphal stages, and since the outer shell or cuticula cannot expand to accommodate the increase in size or change in form, it is cast off during the process of *molting* or *ecdysis;* no growth takes place in the pupal stage, or in the adult insect after it has acquired functional wings.

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*B(28) All living things receive and respond to stimuli in their environment.

E(33) The majority of insects of a particular species respond to external stimuli in a similar manner, the response depending upon preceding activities of the nervous system, and upon other physiological conditions.

B(29) Almost all organisms carry on cellular respiration, or gaseous exchange, whereby oxygen is obtained from air, water, or other surrounding medium, and carbon dioxide is given off with release of energy and building of new protoplasm.

E(34) Under certain conditions, the hemoglobin in the blood of certain insects carries oxygen, but generally adult insects breathe through paired spiracles usually located on the last two thoracic and first eight abdominal segments, the oxygen dif-

fusing into cells in all parts of the body after being carried there, through respiratory movements, by a network of branching tracheal tubes and fine tracheoles; carbon dioxide is eliminated through the tracheae and body surface. Insects which lack or have an imperfectly developed tracheal system breathe directly through the integument or skin (parasitic larvae and springtails), and in many parasitic larvae exchange of gases takes place between the tissue fluids of parasite and host; exchange of oxygen and carbon dioxide in most aquatic larvae takes place through the skin, and in addition some breathe by means of a rich network of fine tracheoles called "tracheal gills."

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*B(30) Most organisms have appendages which are specialized to perform certain functions.

E(35) Most adult and larval insects have a single pair of sensitive, segmented *antennae* or "feelers" usually located between the eyes or above the bases of the mandibles, but they are reduced or absent in primitive wingless insects and in most larvae of highly developed Hymenoptera (ants, bees, wasps) and Diptera (flies); antennae may have functions of touch, taste, smell, hearing, detection of danger by reaction to air currents, location of mates, and communication with other insects.

B(31) The metabolism of an animal results in the formation of useful chemical substances called *secretions*, which are elaborated by special glands, and may be used locally or at considerable distances from the cells in which they are produced.

E(36) The single-celled and many-celled glands of insects arise from all parts of the body wall, from the anterior and posterior portions of the alimentary canal, and from reproductive ducts, and produce substances such as saliva, mucus, milk, wax, lac, dyes, adhesive fluids, repellent and offensive odors and fluids, alluring scents, egg coverings, molting fluids, and others.

B(32) Some degree of regeneration is found in all living things; as an animal becomes more complex there is a decrease in the ability to regenerate lost parts.

E(37) As a rule regeneration or regrowth of lost appendages can take place only at molting, and is therefore limited to the younger stages, but in some mantids and primitive wingless insects it can occur in adults.

B(18) Food is necessary to the continued existence of all living things, in order to supply fuels (fats and carbohydrates) as sources of energy, materials (proteins) for growth and repair of tissues, and substances (minerals, vitamins, water) for regulating body processes.

*B(33) Many organisms possess structures for storing reserve food substances.

E(38) All insects possess a tissue *(fat body)* which stores nutritive and energy-forming substances, such as fat, glycogen, and protein, which are drawn upon during hibernation. molting, metamorphosis, egg development in the female, and sex maturation in the male and female; the fat body consists of loose clumps of cells joined by connective tissue strands, arranged in a constant manner for each species, and may be distributed as a layer just beneath the skin, around the organs in the thorax and abdomen, in the dorsal and ventral body cavities, and in the head and appendages.

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*B(34) Many organisms possess specialized sense organs which are sensitive to particular kinds of stimuli in their environment.

E(39) The sense organs of insects are widely distributed over the surface of the body and its appendages, and also occur in the anterior and posterior portions of the alimentary canal; all sense organs consist essentially of a nerve of the central nervous system which communicates with one or two modified hypodermal cells, and external supporting or accessory structures such as body hairs (setae), tubercles, or pits.

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*B(35) Most animals have organs of vision to enable them to see what goes on in their environment.

E(40) Most adult insects have two lateral compound eyes composed of hundreds or thousands of hexagonal, transparent facets or corneas, beneath each of which is a visual element (ommatidium) which detects motion and has a narrow angle of vision, so that a mosaic-like image is formed; between the compound eyes, and also in certain larvae and nymphs, there are simple eyes with single facets (dorsal ocelli, typically 3 in adults), which are stimulatory organs, increasing reflex reactions to stimuli received by the compound eyes; larvae of insects which undergo a complete metamorphosis perceive light by means of lateral simple eyes (stemmata) of variable structure and number (1-8); in blind insects, the general body surface is sensitive to light.

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*B(36) Every organism inherits certain fixed reactions or kinds of behavior which are characteristic of the particular species to which it belongs.

*E(41) A great deal of the behavior of insects consists of orientation to stimuli by means of forced movements or "taxes" which, in general, are constant for each species.

B(37) The internal secretions of endocrine glands are absorbed directly into the blood or lymph from glands producing them, circulate through the body, and are absorbed by organs whose activities are regulated by these hormones.

E(42) All insects have small, many-nucleated granular masses or bodies called *corpora allata* lying behind the brain in the head, neck, or first segment of the thorax, closely associated with the visceral nervous system, and are glands of internal

secretion which produce the hormones that bring about molting.

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*B(30) Most organisms have appendages which are specialized to perform certain functions.

E(43) Most adult insects have one or two pairs of *membranous wings;* if there is one pair, it is usually borne by the middle segment of the thorax, but if there are two pairs, the second pair is borne by the last segment of the thorax, and is sometimes folded under thickened fore wings; each wing has cuticular veins, constant for each species, with rigid, non-chitinous walls which were formed around pre-existing tracheae, and serve to strengthen the wing and adapt it to flight movements.

E(44) Typically, adult insects have three pairs of *jointed legs* adapted to perform various functions, each leg being composed of the following segments: coxa, trochanter, femur, tibia, and tarsus (commonly composed of 2-5 subsegments); a pretarsus, or terminal foot structure bearing a pair of lateral claws, may be withdrawn into the last segment of the tarsus, or may not be present as a distinct segment.

B(18) Food is necessary to the continued existence of all living things, in order to supply fuels (fats and carbohydrates) as sources of energy, materials (proteins) for growth and repair of tissues, and substances (minerals, vitamins, water) for regulating body processes.

*B(38) Water is essential to protoplasmic activity of all living things.

E(45) The amount of water needed by an insect depends on the rate at which it is lost by the body, this being influenced by the properties of the cuticula, the action of the respiratory and excretory systems, and by the drying power of the air or other surrounding medium.

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*B(39) Some animals possess specialized respiratory structures for increasing the volume of inspired air.

*E(46) Many winged insects possess rapidly-filled dilations of the tracheae called *air sacs*, which greatly increase the volume of the inspired and expired air, and lower the specific gravity of the insect, thus assisting in flight.

B(40) From the simple to the complex animals, there has evolved an increasingly complex arrangement of groups or nets of nerve cells, called the receptor-effector or nervous system, in which irritability and conduction are highly developed.

E(47) The central nervous system of insects consists of a complex nerve mass in the dorsal part of the head called the *brain*, and a ladder-like chain of connected, segmental ganglia forming the *ventral nerve cord* lying beneath the alimentary canal; below and behind the brain there is a *subesophageal ganglion* composed of three fused ganglia, and the ganglia of the ventral nerve cord tend to unite with one another in various combinations in different insects; the nerves of the visceral (stomatogastric) nervous system innervate the muscles of the fore-intestine, salivary ducts, aorta, corpora allata, and some mouth parts; the peripheral sensory nervous system, consisting of a fine network of nerve and sensory cells lying beneath the skin, is best developed in soft-skinned larvae.

B(41) Digestion in plants and animals is carried on by enzymes, or organic catalysts, which make food soluble so as to allow nutrients to be absorbed by osmosis into cells, and also reduce complex fats, proteins, and carbohydrates to simple building materials which are assimilated by the body and changed into protoplasm.

E(48) Insects have a *fore-intestine* and a *hind-intestine* lined with a cuticula which is continuous with that covering the body surface, and between these is the *mid-intestine* (stomach, ventriculus) where most digestion and absorption take place; in many insects the hind-intestine absorbs water from the feces.

B(42) Internal distribution by circulation is carried on in all organisms; in simple forms, the circulation of living protoplasm within the cell itself, or from cell to cell, is adequate for distribution of substances, but in more complex organisms there is a special circulatory system for transporting food, oxygen, and wastes to or from distant parts of the body.

E(49) Insects have an open circulatory system, there being only one closed, suspended, pulsating dorsal vessel, consisting of the *heart* with lateral inlets (ostia) in the abdomen, and the *aorta* in the thorax and head; most of the circulation takes place in the cavities or sinuses of the body and its appendages, and is maintained in a posterior-anterior direction by a system of muscular pumps and fibro-muscular septa or diaphragms.

B(43) In organisms, the end products of metabolism—water, carbon dioxide, inorganic salts, and nitrogenous wastes—are usually eliminated from the body during the process of excretion, or stored in cells as insoluble crystals.

E(50) The principal excretory organs of insects are the long, slender *Malpighian tubes*, 1-150 in number, closed at one end and opening into the mid-intestine, hind-intestine, or between the two; they remove the waste products of metabolism from the blood by which they are bathed, and the resulting urine is mixed with undigested food and eliminated as feces; calcium salts and uric acid are frequently stored in the tubes in the form of crystals, but in some insects which lack Malpighian tubes uric acid is stored in urate cells of the fat body, while others have tubular excretory glands in the head.

B(44) The power of contractility, which results in movement, is possessed by all protoplasm to a greater or lesser degree, but is highly devel-

oped in muscle cells, which react when stimulated by impulses coming chiefly through the nervous system.

E(51) The very numerous, cross-striated, segmentally arranged *skeletal muscles* of insects have their origins at the body wall and its internal projections; the *visceral muscles* consist of longitudinal and circular fibres, as around the gut, or of irregular branches, as in the muscles associated with the heart, ventral diaphragm, covering of the ovary, and stomach wall.

B(45) The cell is the unit of structure and function in all living things; every cell consists essentially of a mass of protoplasm which is usually differentiated into a denser central portion, the nucleus, and an outer portion, the cytoplasm.

E(52) In the growing stages of insects, the cells of the epidermis (or hypodermis), which is the active living part of the body wall, are usually cubical or columnar in shape, with nuclei near their bases; but in adult insects, after the epidermis has produced the hard cuticula, the cell boundaries are indistinct, cell areas are marked only by the nuclei, and a basement membrane forms the inner lining of the body wall.

As indicated in Part I of this article, 52 (45 major and 7 minor) principles of entomology are subordinate or related to 45 (27 major and 18 minor) principles of biology. The following relationships are also evident:

(a) Thirty major entomological principles are subordinate to 23 major principles of biology.

(b) Fifteen major entomological principles are subordinate to 15 minor principles of biology.

(c) Seven minor entomological principles are subordinate to 7 minor principles of biology.

Thus a major principle of entomology may be based upon a minor, as well as a major, principle of biology. This is possible because entomology is a subdivision of biology.

It is important to note that these principles are not listed in the order which instructors usually follow, but are listed from more important to less important according to their general educational value, based on the extent to which they meet the criteria of general education.

CONCLUSIONS

In the light of the findings presented in this study, and in keeping with the scope, procedure, and limitations of the investigation, the following conclusions seem to be warranted:

(1) Principles of entomology are suitable for inclusion in a biology course for general education, since it has been shown that they meet the various criteria or objectives of general education.

(2) The knowledge and comprehension of the principles of entomology has cultural value, leads to an understanding, of basic scientific concepts, leads to the understanding and control of the natural environment, leads to the development of interests, has practical application, and contributes to reflective or critical thinking.

(3) The principles of entomology which have greatest significance for general education are those which pertain to man's economic welfare and health, and to methods of insect control.

(4) The principles of entomology which have considerable value for general education include those which relate to the effect of the environment upon the activities of insects, abundance, distribution, and reproduction.

(5) The principles of entomology which have least significance for general education are those which describe basic anatomical features of insects.

RECOMMENDATIONS

The conclusions lead to the general recommendation that, in teaching the fundamental principles of entomology, more attention should be paid to the social implications of the principles than to basic anatomical facts, although the latter are important in ascertaining which organisms are insects, and which methods of control are to be used. It is not intended that the principles of entomology be delivered to the student with instructions that they be memorized. It is, however, suggested that

the instructor draw upon the experiences and observations of the student, so that the principles of entomology may be built up about the applications and social implications already known to the student. By so doing, the study of entomology will be vital and interesting instead of being a dull and routine recital of unrelated facts.

The list of principles of entomology secured in this investigation will prove to be of considerable value to high school and college teachers in the following ways:

(1) As a source of technically correct entomological statements which may prove useful in drawing up a "unit" of entomology in the biology course for general education, or in including sound entomological material in the course of biology, whatever the plan of organization may be.

(2) As an indication of the relative importance of principles of entomology, so that the instructor who is pressed for time may better ascertain which principles are to be stressed in accordance with the time allotted to the "unit" on entomology, or to the entomological content of an organization of biology which does not treat the subject of entomology as a particular "unit".

Entomology should be included in a biology course for general education, both in the high school and college, because it has something to contribute toward effective living, and toward an understanding of the environment. However, the extent of the principles taught, and the extent of the associated facts, depends upon the nature of the curriculum and course in each institution. The high school teacher must of necessity present the principles of entomology in a more elementary manner, with the stress placed upon social implications. The college instructor should not try to present too many details to students who desire entomological knowledge for general education. Rather, his objectives should also include the social implications of entomology, and a better adjustment to the world in which we live through an understanding of vital problems in relation to man's health, comfort, and economic welfare.

SOCIAL IMPLICATIONS OF ENTOMOLOGY

The social implications of entomology are numerous because of the effects of insects upon man's economic welfare and upon his physical and mental health. If many crops are destroyed and many domestic animals weakened or killed, the result is a decrease in the amount of available food, including fruit, vegetables, meat, milk, eggs, seeds, and their products. Lack of suitable food may have a tremendous effect upon the activities of a group of people, with possible international implications. For instance, insects destroy millions of dollars worth of rice plants annually. The annual loss in the United States from the rice weevil's destructive activities amounts to $2,150,850 (13). During the period 1930-1933, the loss from the rice stinkbug in Louisiana, Texas, and Arkansas amounted to $2,139,952 (13). Undoubtedly then, if such destructive insects were to ravage the rice crops in a country whose major foodstuff is rice, such as China, then mass starvation might result, and perhaps lead to undesirable political activities and armed conflict, with international repercussions.

There are many social implications of malaria and the malaria mosquito. Malaria is the most important disease of the tropics because it has limited the industrial and agricultural development of these regions, and because it has taken a great toll of human lives. Williams (14) states that in the southern part of the United States one-third of the working time was lost to the malaria mosquito, up to a few years ago. In hot countries the loss in time is often greater, varying from 50 to 75 per cent. From studies of the death rate, industrial losses, and farm slowdown, the average annual loss in the United States from the malaria mosquito is not less than $500,000,000 (14). There is an estimated average of 4,000,000

cases a year, and 4,000 deaths annually in the southern United States. In India the problem is much more serious, with about 100,000,000 cases and 1,000,000 deaths annually from malaria. During World War II thousands of our troups were incapacitated and made unfit for active duty by malaria, which they acquired on the islands of the Pacific Ocean, in Africa, Europe, and Asia.

Insects transmit many other diseases to man, such as yellow fever, filariasis leading to elephantiasis, dengue or breakbone fever, myiasis, human encephalitis, typhus fever, trench fever, relapsing fever, bubonic plague, tularemia, helminthiasis, kala azar, amebic dysentery, Asiatic cholera, yaws, erysipelas, anthrax, Rocky Mountain spotted fever, sleeping sickness, scabies, oriental sore, and others.

Among the diseases which insects transmit to domestic animals are Texas fever, encephalitis, swampfever, fowl spirochaetosis, and various forms of sleeping sickness such as surra, dourine, nagana, and mal de cadera. Insects also cripple and kill domestic animals by their feeding activities which cause severe inflammation, running sores, ulcerous conditions, and loss of blood, vitality, and production of valuable foodstuffs.

Among the plant diseases transmitted by insects are: fungus diseases, such as Dutch elm disease, chestnut blight, ergot of rye, red rot of sugar cane, and early blight of potatoes and tomatoes; bacterial diseases, such as bacterial wilt of cucumbers, melons, corn, potatoes, tomatoes, and peppers, bacterial soft rot of cabbages, potatoes, and apples, and fire blight of apples and pears; virus diseases, such as curly top of beets, aster yellows of about 200 species of plants, dwarf disease of rice and onions, leaf roll of potatoes, mosaic disease of sugar cane, corn, tobacco and cabbage, and yellow spot of pineapples; and diseases caused by the introduction of toxic substances, such as psyllid yellows of potatoes, mealy-bug wilt of pineapples, froghopper blight of sugar cane, hopperburn of potatoes, and Anasa wilt of pumpkins and squash.

Many men have been employed as a result of the work of insects. Many are steadily engaged in insect control, such as spraying, dusting, and fumigating. The United States Department of Agriculture employs hundreds of men to inspect the baggage, cargo, stores, and ballast of ships and planes arriving from foreign countries, to intercept plants and plant products which may be infested with insects or plant diseases. Domestic quarantines are also carried out, to prevent the spread of dangerous pests and diseases from one state to another. Many entomologists are employed as college instructors or professors, as research men in agricultural experiment stations, or with insecticide companies. Also, foresters are employed in many countries in order to maintain and conserve forests, and to reduce the amount of insect infestations.

Man has clothed himself with a most valuable insect product, silk. Few realize that shellac is made from the secretion of a tiny scale insect. This substance has been used extensively in making polishes and varnishes, in finishing woods and metals, for stiffening hat materials, in making lithographic ink, phonograph records, linoleum, buttons, planes, shoe polishes, pottery, toys, artificial flowers, and artificial fruit. Beeswax, produced by worker bees, is used in the manufacture of candles which are nearly smokeless, shaving cream, cold cream, cosmetics, floor waxes, models, crayons, carbon paper, and electrical and lithographing products.

A knowledge of entomology may make or break one who farms for a living. The most valuable weapon that can be used to combat an insect is an intimate knowledge of the insect itself—its life history, natural enemies, susceptibility to high and low temperatures, and the effect of moisture upon its increase or decrease in numbers.

The many social implications of ento-

mology and their ramifications thus justify the study of the principles presented above. They have withstood the test of being matched against the criteria of general education. The student who does not intend to become a biologist or entomologist will, through the study of these principles and their applications and implications in daily life, become better adjusted to the various aspects of his environment.

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AN ANALYSIS OF A LABORATORY STUDY DESIGNED TO TEACH THE SCIENTIFIC METHOD*

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The eight rules used by the author for guidance in the construction of laboratory outlines was discussed in a preceding number of this journal.†

One of the outlines, Studies, written on the basis of these rules is presented in the following pages. The Study is discussed largely from the point of view of the rules used in its construction. Briefly stated these rules are:

1. List all the topics and facts which might be included.

2. Assume at the start that the orthodox treatment of the subject is not good and resolve to use as little of it as possible.

3. Write the laboratory study near a laboratory where each step can be tested as it is being written.

4. Take plenty of time so that original thoughts will have time to incubate.

5. Present facts as the results of experiments by demonstration, by having students make observations, by giving preliminary information, or any other feasible method.

6. Have the student state a hypothesis or hypotheses based on the facts.

7. Have the student choose the best hypothesis and test it by the accumulation

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of other facts, preferably those derived from experiments he himself has devised.

8. Have the student accept, restate, or reject the tested hypothesis.

It is hoped that the reader will not look for perfection in any phases of this work, but rather for suggestions that may prove helpful in developing his own manual along similar lines. Both the rules and the Studies based upon them are in a state of flux. However, the effectiveness of these Studies in the classroom has been sufficiently good to warrant an examination by other teachers.

The answer spaces after questions have been omitted from the Study presented in the following pages in order to condense the material. Wherever such space has been omitted the abbreviation, A.S.O. (Answer space omitted), has been inserted. Part XII which deals with the effect of temperature on photosynthesis has also been omitted here because it adds nothing to this discussion.

The Study was written to be used in the third and fourth periods of a college basic biology course. It is preceded by two Studies: "Observation and Use of the Microscope" and "The Scientific Method." The first Study aims to bring out that good observation is always accompanied by mental activity. The second Study tests a single hypothesis dealing with differences between male and female students.

This Study on photosynthesis is designed to carry the student a little further along in his training in the use of the scientific method. It is an advance over the preceding Study by requiring the student to formulate his own hypotheses, by dealing with several hypotheses, by using established hypotheses as a partial basis for others, and by requiring in two instances more than one hypothesis to be formulated from the same factual basis.

The discussion of the scientific method in the introduction is rather incomplete in itself but is designed to carry the student further than was done in the previous Study and to serve as a basis for development in the Studies that follow.

The list of topics and facts to be treated were drawn up approximately as follows:

A. Gaseous exchange between leaf and atmosphere
  1. CO_2 absorbed by the leaf
  2. O_2 released from the leaf

B. Structure of the leaf
  1. Epidermis
  2. Stomates and guard cells
  3. Mesophyll

C. Organic products of photosynthesis
  1. Sugar first product
  2. Starch forms from sugar immediately
  3. Starch granules in chloroplasts
  4. Disappearance of starch from the leaf

D. Nutrition of the plant and photosynthesis

E. Chemical tests
  1. Starch
  2. Glucose

F. Factors necessary for photosynthesis
  1. CO_2
  2. Chlorophyll
  3. Light
  4. Living protoplasm
  5. Favorable physical conditions
  6. Water
  7. Minerals

G. Other pigments associated with chlorophyll
  1. Carotin
  2. Xanthophyll

The orthodox method of dealing with photosynthesis was mentally discarded when the work on the outline was begun. Also a considerable amount of time was taken so that all steps could be laboratory tested as they were written. Despite this adherence to rules 3 and 4, the reader will recognize the almost complete dependence of this Study on the usual laboratory techniques used in elementary biology teaching. The rules however led to some fruitfulness such as the overall treatment, the transport

of the student into a study of anatomy on the basis of physiology, and the linking up of nutrition with photosynthesis.

A few facts are presented in the section titled *Preliminary Information.* It was necessary to give some facts in this way because this Study comes early in the course and cannot be made too difficult. Also it was necessary to keep within the limits of two two-hour periods. It is not desirable, however, to use this means of presenting factual material if other means can be found.

In Part I dealing with the test for glucose, the student is expected to come to a tentative conclusion as to what the test for glucose is. It is hoped that he is made aware of the scant basis for this conclusion and values the conclusion accordingly. Part II treats the test for starch in a similar manner.

Part III teaches more technique, but primarily its purpose is to establish some facts which will permit the statement of two exceedingly simple hypotheses concerning the relation of light to photosynthesis. The problem of testing the hypothesis is introduced here. Perhaps by attempting to simplify the step and lead the student to use the glucose test, the initiative is taken from him for devising a better experiment. Part IV adds more information by establishing tentatively the fact that carbon dioxide is necessary for photosynthesis. By repetition it gives more practice in the formulation of a hypothesis, but it fails to bring in the important step of putting the tentative conclusion to test.

In Part V the best opportunity for developing hypotheses is exploited. This Part deals with the effect on photosynthesis of vaseline coatings over leaf surfaces. The student is led from the observations on physiological processes into a study of structure. This approach has been, and is being, used constantly in research. For instance Dubos* in describing a modern approach to the determination of cell structure quotes Claude Bernard (1855-56) thus: "Anatomical localization is often revealed first through the analysis of the physiological process." Such an approach is desirable in elementary teaching because, in general, it allows the student to test his hypothesis by making observations, and observations are the simplest means of giving the student opportunity to secure the testing facts.

By requiring more than one hypothesis on the basis of the same facts, the student is placed in a situation where memory alone cannot supply the answers. If he has had a good biology course in high school, he may state the first hypothesis thus: "The lower surface of the leaf has more openings through which air can enter than does the upper surface." This obviously has required no thought in the sense that thinking is a process of logically interrelating facts in terms of something as yet unkown. When he comes to the second hypothesis, he is definitely on his own and nothing but a little thinking can help him if he does his own work.

He will state something in this second hypothesis which will not agree with the text book, such as: "The cells near the lower epidermis are more active in photosynthesis than those near the upper", or "There are more cells carrying on photosynthesis in the lower half of the leaf than in the upper half." Many will probably say that is poor pedagogy to bring in misinformation. This is undoubtedly true when the aim of instruction is to dispense facts, but is it true if the aim of instruction is to teach scientific thinking?

At the end of Part V the question gives a hint as to the direction the students thoughts might take in trying to formulate a hypothesis. By first asking for the hypotheses, then giving hints, and then telling the student to proceed with the next Part if he can come to no conclusion, it is hoped that for the conscientious student three levels of difficulty are provided. This treat-

*Dubos, R., *The Bacterial Cell,* 1945, Harvard University Press.

ment allows opportunity for all types of students to function at their level of capability.

Part VI provides the material necessary to bring out facts needed to test a hypothesis from Part V, provided that hypothesis involves leaf structure. The use of charts and text pictures to supplement the students' observations is not ideal, but until supply houses can turn out leaf sections of superior quality this seems to be a necessary expedient. The questions at the end of this part, aside from the first, are leading questions to bring out the structural features having to do with absorption and release of gases.

Part VII dealing with variegated and albino leaves and Part VIII dealing with potassium deficient leaves give more practice in the formulation and testing of hypotheses. Use is made of the laboratory techniques already established and the student is allowed to devise his own means of testing. Portions of these are very time consuming and can be carried out only in small classes in well equipped laboratories. Part VIII introduces something new to the elementary study of photosynthesis. Evidence here not only adds support to the hypothesis stated in Part VII, but it brings in the much neglected topic of the necessity of minerals in photo-synthesis.

Part X was designed to bring out the fact that living protoplasm is essential to photosynthesis. The author's colleagues after having taught this Part are quite agreed that as it stands it has failed to do this. This much however can be said in its defense: it does cause a flood of student questions and it does generate many situations advantageous to the teaching of scientific thinking.

Part XI is a problem using red leaves in which both the techniques and the previously established facts are utilized. Here again three levels of difficulty are offered, the last and undesirable step being undirected experimentation, that is, experimentation not designed to test a preconception. No matter what the student does the problem will clarify because any test he knows requires boiling the leaf in water and such treatment reveals the presence of the chlorophyll. For the good students this will usually be the critical fact needed to test the hypothesis; for the poor student it will be an additional fact and will enable him to come to some conclusion. The outline as it stands needs modification to make the two pathways clear.

Study Questions and Problems were designed to occupy the fast student until the end of the period and to supply study material outside of class. An attempt is made here to have the student summarize the facts brought out in the Study and to present thought provoking questions so these facts can be more firmly and logically fixed in the memory.

The various Parts of this outline have been presented by demonstration or for individual student or small group participation according to the facilities and materials available. This type of outline is very flexible and can, with a little modification, be made to fit all sorts of situations. Modifications should be made, however, in the fact presenting portions so as not to destroy the thought situations. It should be constantly kept in mind that the facts are subsidiary to the process of arriving at and testing a conclusion.

Despite the attempts of the author to make laboratory directions so complete that the average student need only be told the location of materials, it has been found that this type of a laboratory Study requires better and more diligent teaching than the usual descriptive-type laboratory outline. When the criterion of value of a student's answer is logicality on the basis of the facts available, then the teacher's mind must be capable of ranging in all directions and must be constantly active. Such teaching is exacting work yet there is a freshness and novelty about it which makes each class a new and broadening experience for the teacher.

PHOTOSYNTHESIS*

Studies 3 and 4

PURPOSES

To observe experiments and formulate hypotheses on the basis of observations.

To test the validity of the hypotheses by experiment and by further observation.

To accept, modify or discard the hypotheses on the basis of the testing.

To learn some fundamental facts concerning photosynthesis.

INTRODUCTION

In the orderly thinking of the scientific method it is necessary to arrive at temporary conclusions on the basis of available information. A temporary conclusion is called an *hypothesis.* It is a statement which explains or interrelates the facts used as a basis in its formulation; it is a decision about the unknown in terms of the known. An hypothesis which has gained support from the collection of further facts or by experimental testing is placed on a higher level and is more readily accepted as being true. A fully substantiated hypothesis is accepted as a fact and as such is used in the formulation of new hypotheses. In careful thinking one should know the facts used as a basis for an hypothesis, should know how long an hypothesis has been held in the mind, and should know if further information has been brought to bear so as to test the hypothesis.

The testing of an hypothesis by experimentation is called the *experimental method* and is one of the major parts of the scientific method. Experiments, correctly devised and executed, enable a scientist to substantiate, disprove or modify an hypothesis in a relatively short period of time. Much of the success of the scientist is determined by his logical and imaginative thinking in the formulation of his hypothesis and by his skill in devising and carrying out experiments to test the hypothesis.

An hypothesis in a loose sense may be spoken of as an *inference* (a tentative conclusion) and the act of its formulation as *inferring* although in a stricter sense the term "induction" is used. An hypothesis which has withstood many tests may be called a *theory* and the theory in turn after considerable substantiation becomes a fact or a biological law. Facts, theories and biological laws are called *principles* when they are explanations, or point out interrelationships, on a broad scale. For example, the basic principle of sexual reproduction is: the first cell of a new individual arises by the fusion of two cells. This principle was at first an hypothesis, later a theory, and is now a biological law.

PRELIMINARY INFORMATION

Photosynthesis is a chemical process by which simple sugars, chiefly glucose, are formed in plants. Because this process is the *ultimate source* of all our organic food, it is desirable to know more about it. Most of the questions concerning photosynthesis remain to be answered, but the discoveries of the past have made available much information of basic importance. It is the most fundamental of this material that will be dealt with here.

When suger is formed in a leaf by photosynthesis it is usually converted immediately into starch which is insoluble and hence does not move out of the cell. To determine whether photosynthesis has taken place, we test for the presence of starch or glucose. The green pigment, *chlorophyll,* in leaves can easily be dissolved out by boiling the leaves in alcohol. If a leaf is cut into small pieces and boiled 4 to 5 minutes in a small amount of distilled water, the glucose can be extracted.

The following experiments are to be done by you or demonstrated for you by the instructor. Be sure to record the results as soon as they are observed and to answer the questions in each part as soon as possible. Keep all leaves on which tests have been made until the end of the period.

PART I

Add 2 drops of alkaline-copper solution (Benedict's solution) to test tubes containing 2 ml. (2cc.) of each of the following solutions (Table 2) and heat in a water bath 4 to 5 minutes. Record the colors present after heating.

Table 2. Color Reactions with Alkaline-Copper Solution

Substance tested	Color after heating
Water	
Starch	
Glucose solution, full strength	
Glucose solution, half strength	
Glucose solution, quarter strength	
Salt solution	

From these observations state what you think is a test for glucose. Be complete and specific in your statement. (Answer space omitted.)

On the basis of the observations do you consider this a statement of fact or an hypothesis? (A.S.O.)

Are you willing to accept your conclusion or would you like further information. Why? (A.S.O.)

PART II

Add a drop of iodine solution to each of the following substances (Table 3) and record any color change observed.

Table 3. Reactions with Iodine Solution.

Substance tested	Color with iodine solution
Egg white solution	
Meat fat	

*This Study is taken from the *Guide for Laboratory Studies in Basic Biological Science* by the Department of Biological Science, Michigan State College. Copyrighted 1946.

Dry starch
Water
Starch solution
Glucose solution

From these observations state what you think is a test for starch. Be complete. (A.S.O.)
Would it be correct to say that you inferred this to be true and that this statement is an inference? (A.S.O.)
Is this statement a theory? Why? (A.S.O.)

PART III

Run the following test on ¼ of a leaf from a plant kept in the dark and on ¼ of a leaf from a plant kept in the light. Mark one leaf by cutting the blade.

Fill a 250 ml. beaker ¼ full of water, bring to a boil, place the leaves in the boiling water for one minute, transfer the leaves to a 50 ml. beaker containing 20 ml. of alcohol (about ½ inch deep), boil the alcohol containing the leaves by placing the small beaker inside the 250 ml. beaker containing the boiling water. *CAUTION.* Alcohol is inflammable; do not get it near an open flame.

After boiling for 5 minutes, lift the leaf from the alcohol with a pair of forceps. What change has taken place in the color of the leaves? (A.S. O.)

What has become of the green pigment? (A.S.O.)

When the leaf has become white or almost white, place it in a small dish, cover with iodine solution and leave for 5 minutes. Remove from the iodine, place in a shallow dish and observe against a white background. Record the observations in Table 4 and keep all leaves until the end of the laboratory period.

Table 4. Test on Leaves of Plants Kept in Light and in Dark.

Treatment. Leaf from plant kept in	Dark	Light
Color of leaf before going in alcohol		
Color of leaf after boiling in alcohol		
Color of leaf after treating with iodine		

On the basis of these observations and your knowledge of the starch test (Part II), what inference can you make (state an hypothesis) concerning the relationship of light to the presence or absence of starch in the leaf? Be specific. (A.S.O.)

Using the preliminary information given at the beginning of the study as well as the observations in Parts II and III, what hypothesis can you make concerning photosynthesis and light? (A.S.O.)

Outline below an experiment to test the foregoing hypothesis. Reread the preliminary information for a hint. If materials are available and time permits, carry out the experiment. (A.S.O.)
Result: (A.S.O.)

Does the result support the hypothesis? (A.S.O)

PART IV

Repeat the procedure of Part III (in which the chlorophyll was removed and the iodine solution added) using a leaf from a plant grown for 24 hours in the light and in air which lacks carbon dioxide.

The plant was kept under these conditions by sealing it in a glass bell-jar along with a beaker containing a chemical (sodium hydroxide) which absorbs all the carbon dioxide in the jar. A lamp was placed near by so the plant was well lighted while in the jar.

Observed result: (A.S.O.)

Is starch present or absent? (A.S.O.)

On the basis of this decision, what inference can you make concerning the relation of carbon dioxide to photosynthesis? (A.S.O.)

PART V

The procedure in Part III (the starch test) is to be repeated using three leaves from a plant grown in the dark 2 days, treated with Vaseline, and then kept in the light 12 to 24 hours. Before being placed in the light the leaves were treated thus: (1) the first leaf was covered evenly over the whole of the upper surface with a layer of Vaseline, (2) the second was covered with Vaseline on the lower surface, (3) and the third was covered with Vaseline on both surfaces. Before the starch test was run on these leaves, the Vaseline was removed. Observed results of the tests:

Leaf (1) (A.S.O.)
Leaf (2) (A.S.O.)
Leaf (3) (A.S.O.)

Keeping in mind:

(1) the preliminary information,
(2) the observations and conclusions, in Parts II, III and especially IV,
(3) the fact that air is composed of nitrogen, oxygen, and carbon dioxide,
(4) and knowing that Vaseline prevents the passage of air,

can you offer two tentative explanations, hypotheses, for the results observed above? Your hypotheses should take into account the differences between leaves 1 and 2, 1 and 3, and 2 and 3.

1. (A.S.O.)
2. (A.S.O.)

Are either of your hypotheses of such a nature that a microscopic study of the leaf would support or discount the hypothesis? (A.S.O.)

If you have imagined no relationship between the experiment of Part V and the possible structure of the leaf, continue into Part VI and see if a relationship becomes evident. If you can imagine a relationship, you are in a position to utilize more fully the observations to be made in the next part and you will be able to check your hypothesis.

PART VI

All leaves which are supported horizontally on plants have much the same arrangement of

cells, hence information secured in Part VI can be applied to all leaves in this study except corn.

Examine the surface of a leaf under the low power of the demonstration microscopes. Do you see anything which supports your hypothesis in Part V? Observe carefully. (A.S.O.)

Now examine at the demonstration microscopes the upper and lower *epidermis* (the outer layer of cells) of a leaf. These have been separated from the other tissues of the leaf. With the aid of charts and textbook pictures determine what the small circular structures are that you observe in the epidermis. Name? (A.S.O.)

Count the number of these in one low-power field of the upper epidermis and the number in one low-power field of the lower epidermis and record in Table 5. Also record here the counts by other class members and compute the average.

Observe the demonstration microscopes, the charts and your textbook pictures which show the structure of leaves. Study these while you answer the questions below. Keep in mind that stained sections have entirely different colors than natural tissues. In the living leaf all the structures are largely colorless except the green bodies, chloroplasts, in the protoplasm of most cells.

Table 5. Number of Stomates in the Upper and Lower Epidermises

Upper epidermis Lower epidermis
Average:
Average:

Questions

1. On the basis of these observations on the structure of the leaf, do you think that your hypothesis to explain the observations made in Part V is still good? (A.S.O.)

a. If so, how do the observations in this part add support? (A.S.O.)

b. If not, how would you restate the hypothesis to logically relate all the facts? (A.S.O.)

2. Are the air spaces between the cells interconnected? See your textbook, page 34, Fig. 14. Read the text below the picture if necessary. (A.S.O.)

3. Do you think air from the outside can pass into these spaces without passing through cells? (A.S.O.)

4. Can the gases inside pass outward in the same manner? What basis other than structure do you have for this answer? (A.S.O.)

PART VII

Using a variegated (green and white) leaf from a plant kept in the light, repeat the starch test as in Part III. Make a sketch of the leaf before and after the starch test. Be sure to outline and lable the colored areas.

Observed result: (A.S.O.)

What inference (hypothesis) can you make on the basis of this result? (A.S.O.)

In a flower pot you will find some green and albino (white) corn plants growing. Can you take these and other materials in the laboratory and devise an experiment to test the preceding inference? Outline the experiment and then carry it out.

Experiment: (A.S.O.)

Observe results: (A.S.O.)

If the experiment you have chosen produces only negative results, devise and execute a second experiment. Reread the procedures and results of Parts II and III for a hint.

Experiment: (A.S.O.)

Observe results: (A.S.O.)

Conclusion: (A.S.O.)

PART VIII

The leaves of bean plants grown on soil deficient in potassium become completely yellow at the tips and margins. On the basis of the information gained in Part VII, what can you predict will be the effect of potassium deficiency on the total photosynthesis of the leaf? (A.S.O.)

Some of the potassium-deficient leaves were tested for starch and the results obtained are recorded for you on charts. Observe these results and record below as drawings. Be sure to label the colors present in the different areas of the leaves. (Drawing space omitted.)

What is your immediate conclusion concerning the presence and absence of starch in the two areas on the potassium-deficient leaf? (A.S.O.)

Does this conclusion prove the hypothesis in Part VII to be true, lend support to the hypothesis, prove the hypothesis to be false, or is it unrelated? (A.S.O.)

Explain why you think so. (A.S.O.)

PART IX

A plant which had been kept in the dark for 2 days was placed in a glass jar, the air inside the jar was replaced with carbon dioxide, and the plant kept in bright light for 4 to 8 hours. A test solution of pyrogallol was placed inside the jar just before it was filled with carbon dioxide. In the absence of oxygen, pyrogallol solution remains colorless; in the presence of oxygen it becomes brown. A starch test was run on one of the leaves after the plant had been exposed to light for several hours.

Examine the demonstration set up and the results of the oxygen and starch tests. Is oxygen present or absent inside the jar now? (A.S.O.)

Is starch present in the leaves? (A.S.O.)

What inference can you make on the basis of these observations? (A.S.O.)

Can you think of any factors which might make you doubt the correctness of your inference? Consider here the apparatus and materials used. (A.S.O.)

PART X

Leaves removed from a healthy plant which had been kept in the dark for two days were

killed by dipping in boiling water and then kept in the light for 12 hours. What inference can you make concerning these leaves and photosynthesis? (A.S.O.)

Test this inference by using materials available in the laboratory. Write below your method and the result. (A.S.O.)
Suggest at least two reasons why you might doubt this inference even though your test may have given confirmatory evidence. (A S.O.)

1.
2.

Describe briefly two experiments you could make to clear up your doubts. (A.S.O.)

1.
2.

PART XI

Plants with red leaves grow and reproduce as do green plants. In view of the things that have been learned so far concerning photosynthesis, it would seem that red plants are probably different from green plants insofar as photosynthesis is concerned. State two hypotheses dealing with this matter which can be tested by experimental techniques available in the laboratory.

Hypothesis 1: (A.S.O.)
Hypothesis 2: (A.S.O.)

If your imagination and reason fail you, write out all conclusions arrived at in this study so far and see if you can bring any of them to bear on this matter. (A.S.O.)

If this also fails to stimulate your imagination and reason, try some experimentation and see if that will assist you. If you have stated the hypotheses, perform an experiment which will test one of them.

Record the experiments and results below in brief, yet complete form. (A.S.O.)

If you were able to state the hypotheses without the aid of this experimentation which of your hypotheses is supported by your experimentation? (A.S.O.)

If necessary, restate the hypothesis to make it more nearly correct. (A.S.O.)

Are you willing to accept the hypothesis in this form, or would you like to check it further? (A.S.O.)

STUDY QUESTIONS AND PROBLEMS

1. List all the factors shown in this study to be necessary to photosynthesis. (A.S.O.)
2. Compile a list of all the factors necessary for photosynthesis. This information can be secured from your text, your lecture notes and the above list. (A.S.O.
3. Do the roots of plants carry on photosynsis? Give reasons for your answer based on observations made during this study and on your general knowledge. (A.S O.)
4. Do the petals of red roses carry on photosynthesis? Give a reason for your answer. Examine the rose petals present in the laboratory. (A.S.O.)
5. Do the stems of a tomato plant carry on photosynthesis? Why do you answer as you do? Examine the tomato plant present in the laboratory. (A.S.O.)
6. Does the starch formed in the leaf remain there? (A.S.O.) Can you find indirect support for your answer in the work of this study? (A. S.O)
7. From your knowledge of the composition of air and the results of this study, which of the components of air might become a limiting factor to photosynthesis? (A.S.O.)
8. Why did you eliminate the other components of the air as limiting factors? (A.S.O.)
9. Why is it that albino corn plants never develop to maturity? (A.S.O.)
10. All organisms are made up of cells. Had you formulated this statement from your own observations, would you call it a borrowed opinion, an hypothesis, a theory, or a biological law? (A. S.O.)

Cite the facts you know which you consider a basis for this statement. (A.S.O.)

BIOLOGY — AN EVALUATION

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LAST spring two of us teaching in the Yakima High School decided to ask our Biology classes to evaluate the course. I asked my three Science Four classes to rank the units according to preference, with reasons for first and last choices. Mr. Oliver asked his students to put down favorite and least liked units with reasons for those choices. He also asked them to criticize the course constructively. Both sets of results proved so unexpectedly illuminating that it was thought best to tabulate them with a view to answering the following questions:

1. **Are certain units definitely popular or unpopular, or are all units liked about equally?**
2. **Is there a significant difference between the reactions of boys and girls?**
3. **Is there a significant difference between the reactions of able students and of poorer students?**

4. Is there a difference between the reactions of classes of the two teachers? If so, are these differences due to differences in teaching technics?
5. Do these results suggest changes which should be made in the course?

Results were tabulated from sixty-four papers handed in in my three classes (twenty-four boys and forty girls), and from sixty-four papers from Mr. Oliver's classes (twenty-eight boys and thirty-six girls). This was not all of his papers, for some had been discarded before we decided to work out comparative tables. Numbers were then converted to percents with the results indicated in Tables I and II.

TABLE I

Favorite Units in Biology

Unit	Miss Klise			Mr. Oliver			Combined Classes		
	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total
I.	0.0	7.5	4.7	0.0	0.0	0.0	0.0	3.9	2.4
II.	12.5	15.0	14.2	7.2	2.8	4.7	9.6	9.2	9.4
III.	0.0	0.0	0.0	3.6	2.8	3.1	1.9	1.3	1.6
IV.	0.0	0.0	0.0	0.0	2.8	1.6	0.0	1.3	0.8
V.	8.3	10.0	9.4	0.0	8.3	4.7	3.9	9.2	7.0
VI.	0.0	2.5	1.6	0.0	11.1	6.1	0.0	6.6	3.9
VII.	0.0	5.0	3.0	3.6	2.8	3.1	1.9	3.9	3.1
VIII.	0.0	7.5	4.7	0.0	8.3	4.7	0.0	7.9	4.7
IX.	8.3	2.5	4.7	3.6	8.3	6.1	5.8	5.2	5.4
X.	25.0	25.0	25.0	10.8	22.2	17.1	17.3	23.8	21.1
XI.	0.0	5.0	3.0	14.4	5.5	9.3	7.8	5.2	6.2
XII.	46.0	20.0	29.6	56.8	24.9	39.5	51.8	22.4	34.4

TABLE II

Least Liked Units in Biology

Unit	Miss Klise			Mr. Oliver			Combined Classes		
	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total
I.	12.5	7.5	9.4	7.2	8.3	7.8	9.6	7.9	8.6
II.	18.3	15.0	16.6	7.2	22.2	15.6	7.8	18.5	14.0
III.	0.0	5.0	3.0	3.6	0.0	1.5	1.9	2.6	2.4
IV.	12.5	7.5	9.4	0.0	8.3	4.7	5.8	7.9	7.0
V.	12.5	7.5	9.4	10.8	5.5	7.8	11.5	6.6	8.6
VI.	12.5	2.5	6.3	3.6	2.8	3.1	7.8	2.6	4.7
VII.	0.0	0.0	0.0	0.0	2.8	1.6	0.0	1.3	0.8
VIII.	16.6	10.0	12.4	3.6	11.2	7.8	9.6	10.5	10.1
IX.	16.6	37.5	29.6	53.2	24.9	37.5	36.3	31.6	33.6
X.	4.2	5.0	4.7	3.6	11.2	7.8	3.9	7.9	6.2
XI	4.2	0.0	1.6	3.6	2.8	3.1	3.9	1.3	2.4
XII.	0.0	2.5	1.6	3.6	0.0	1.5	1.9	1.3	1.6

As a help in the interpretation of data, it might be well to put down a summary of the contents of units in the text used, which was the 1943 edition of *Dynamic Biology* by Baker and Mills.

I. Introduction. Scientific attitudes and method; sciences included in Biology; use of the miscroscope in studying one-celled organisms.

II. Classification of plants and animals, campcraft and national parks, flower and vegetable gardening.

III. Advances in agricultural methods, in new uses for farm products, and in medicine; contributions of various biologists.

IV. Manufacture of food by plants; food selection, digestion in plants and animals; disorders of the human digestive tract.

V. Pathogenic bacteria; brief descriptions of cause and cure for a few typical diseases; relation of individual to community health.

VI. First aid; circulatory system, respiratory tract, bones and muscles; alcohol, tobacco and marijuana.

VII. Adaptations of plants and animals to their environment, adaptations for better living and for living in the air age.

VIII Behavior; structure of the nervous system; forces affecting mental health.

IX. Reproduction and embryology in plants and animals; laws of heredity and their application to the improvement of plants and animals; personal and social problems of genetic origin.

X. Paleontology; theories regarding changes and mutations; biological significance of certain world-wide problems.

XI. Vocational opportunities in biological fields; specific knowledge needed by foresters and entomologists.

XII. Conservation; distribution and habits of fishes, birds, mammals, wild flowers, forests; conservation of farm lands.

It is evident that Unit XII was outstandingly popular among all students, although more markedly so among the boys than among the girls. Unit X was also popular, being more so among my students than among Mr. Oliver's. Unit II received a number of firsts in my classes, although nearly as many placed it last as placed it first. Units VI and XI ranked quite high in Mr. Oliver's classes.

The unit which stands out as least liked in all classes was Unit IX, but here we have a curious situation. In Mr. Oliver's classes more boys disliked it than girls and most objected to the section on reproduction and embryology. In my classes only four boys disliked it, while fifteen girls or 37.5% objected, and both boys and girls objected to the section on genetics. Also recalled with no great pleasure in my

classes were Units II (mentioned in the preceding paragraph) and VIII, while in Mr. Oliver's classes, Unit II was the only Unit besides IX to receive a high number of adverse votes. One interesting point is that among neither boys nor girls is Table II the reverse of Table I.

With regard to difference of reaction between boys and girls, one point is obvious from study of the figures. Boys likes and dislikes are more marked than those of girls for the same age group. Considering the favorite unit first, 51.8% of the boys voted for Unit XII, 17.3% for Unit X, 9.6% for Unit II, none for Units I, IV, VI, and VIII, and small numbers for the remaining units. Among girls the largest number of votes cast for any one unit was 23.8% for Unit X, with Unit XII a close second. For the other units, votes ranged between 1.3% and 9.2% with no unit not placed first by at least one girl,

The boys were less unanimous in their dislikes than in their likings, The largest number voting down any one unit was nineteen or 36.3% of the total number voting. The next largest number of boys agreeing to dislike one unit was less than a third of 36.3% with smaller numbers disliking all other units except Unit VII which received no negative votes. Girls also were agreed that Unit IX was least enjoyable, twenty-four or 31.6% voting against it. Fourteen disliked Unit II, and smaller numbers voted against the other units.

In attempting to draw conclusions from these tables, one can not decide from the evidence available whether more students actually disliked or were indifferent to some of the units, or whether so many were so strongly sold on units X and XII that they could not consider others for first place. Possibly a truer picture is obtained by studying the data obtained in the classes which ranked all the units rather than putting down just first and last choices. In computing scores for Table III below, numbers were counted for each chapter for each place. First place was given a value of twelve points, second place of eleven points, and so on down to twelfth place with a value of one point. The median score was figured for each group by assuming an equal number of the total had placed a unit in each place. Then using this median score as 100, the other numbers were converted to percents of one hundred.

TABLE III

PREFERENCE RANK FOR BIOLOGY UNITS

Unit	Boys	Girls	Total
I.	85	98	94
II.	91	100	98
III.	59	89	79
IV.	71	94	86
V.	74	82	80
VI.	not figured*		
VII.	91	92	92
VIII.	77	91	86
IX.	82	88	86
X.	131	118	124
XI.	91	98	96
XII.	151	138	142

*As part of Unit VI duplicates work given in Health classes, only part of this unit was discussed in my classes. For that reason a few students did not rank it, and results were difficult to interpret.

Again Units X and XII were more popular with the boys than were the other units. However the differences between the other units are not so marked, as all but Units III and XII were within 31% of the median, while four units were within 10% of the median. Among the girls, Units X and XII were also favorites, although not by so large a margin as in Table A. All the other units were within 18% of the median, with five units being within 9%.

This would seem to suggest that students ranked units partly according to difficulty encountered, and partly according to interests felt in that field of Biology. If the subject matter ties in with hobbies or with interest in certain vocational fields, the unit will be ranked high regardless of its difficulty. Also since classes are so diverse in activities and interests, the number

disliking a unit will be balanced by another group who find it important to them.

While I can not answer for Mr. Oliver's classes, I found in mine no marked difference in the reactions of able students and of poorer students. For example, Unit IX is undoubtedly the hardest in the book because it contains some rather abstract concepts. Of the three who placed it first, one boy was an honor student with an I. Q. of 125, one was an average student with an I. Q. of 109, and the third a hard-working student with an I. Q. of 69. Distribution of likes and dislikes was similar for the other units.

Some of the differences in reactions of Mr. Oliver's classes and mine probably show the results of differences in teaching the units concerned. As to why Mr. Oliver's students, especially the boys, disliked the section on reproduction, I could not say. One difference might be that while he seats boys and girls at the same table, I try to separate my students. I felt they might feel less constrained while studying the torso in connection with digestion, respiration and circulation; and the greater ease of setting next to someone of one's own sex may have carried over into the discussion of this unit. However that device might not work out so well in his smaller room in which students must sit around a table rather than at one side of it.

In that same unit I think I know why my students, especially the girls, disliked the section on Genetics. The text discusses Mendelian inheritance rather briefly, and I had noticed that the Army examination for high school credit in Biology included quite a few problems on monohybrid and dihybrid matings which were more difficult than anything in the text. Since I felt the book was out of line on that point, I gave my classes extra problems including some work with Punnett squares. Those are rather abstract, and I have found that high school girls are usually less capable of abstract thought than boys. So although they tried, some never glimpsed the principles behind the problems and felt frustrated.

The relatively greater number of students in my classes who liked Unit X may have been sold on it because we took part of one period to look at some National Geographic plates of extinct animals and of the formation of Crater Lake and the Grand Canyon (opaque projections). Then another peroid was spent looking at fossils and talking about the Petrified Forest at nearby Vantage, as well as about local geology and rock polishing.

Unit II includes a great deal of material, and this year I spent more time on it than I shall another year, for the time spent was out of proportion to the number of pages in the unit. In view of the amount of time spent, it was interesting to see that nine considered it the most important unit, and eight liked it least, while according to Table C, it came closer to the median than any other unit.

In summarizing the foregoing discussion we might draw the following tentative conclusions.

1. The units on Paleontology and Conservation tend to be more popular than the others, while the unit on Reproduction and Genetics is least liked for several reasons.
2. Boys either have narrower interests in the biological field or feel more strongly about various subject matter fields than do girls.
3. More boys are interested, some of them keenly so, in topics having to do with the outdoors—agricultural conservation methods, material about game birds and animals, information regarding insect pests, weeds, and rusts.
4. There are no significant differences between the reactions of abler students and of poorer students as both groups tend to like the units which they consider important rather than the ones which are easiest.
5. There were some significant differences between results obtained in Mr. Oliver's classes and mine, some of which will result in changes in methods.

Equally illuminating were the student recommendations for improving the course. They were not only interesting but even more helpful than the tabulation in formulating plans for the following year.

These recommendations by Mr. Oliver's students fall into six groups: (1) recom-

mendations regarding subject matter, (2) criticisms of work books, (3) comments on tests, (4) comments on course organization, (5) comments on films, and (6) request for first hand study of life forms and for projects.

Of the seventeen students commenting on subject matter, seven felt the book should use simpler words, and four thought there should be fewer topics which should be more thoroughly discussed. A single recommendation was found for each of the following topics:

More about plants and animals of this country.
More about plants and animals and less about how they grow.
Reproduction taught in the Health classes.
Outside speakers, for example on narcotics.
Plant and animal identification.
More illustrations in the text.

The dislike of hard words is more commonly expressed now than in the past, and one can understand it from the students who have not learned to read nor to spell --usually non verbal students. However, I am not sure that high school teachers and texts should be expected to keep at the fourth or sixth grade level in vocabulary. In the first place, this handicaps the average and above average students. In the second, precise meanings and explanations can not be given in any science without the use of some specialized vocabulary. So, while we should probably not flunk these handicapped students (if they are truly handicapped and not merely mentally lazy), those students should not expect us to gear our classes completely down to their level of ability.

As to the next point, I sometimes agree with the students who felt that the Biology course is overfull, and that there should be fewer topics which were more fully discussed. It is a point which is still debated in the science magazines. However, the trend has been away from this suggestion, and there is difficulty in deciding which material should be eliminated.

The wish for more about plants and animals of this country may have been a reaction against study of the marine animals which are compared with the more complex ones. To an inlander who has never seen them, sponges and sea anemones and jellyfish may well seem less interesting than the warm-blooded animals. Actually there is quite a bit of material on insects, birds and mammals, both in the United States and (by special reports) of the Northwest.

The student who wanted more about plants and animals and less about how they grow, came to this high school from another state. If we carried out his recommendation it would result in duplication of material taught as natural history or natural science in our grade schools. Difference in background makes quite a problem, and many of our students come from outside the district and from outside the state. This means that material which would be of great interest to one third of a class would be an old story to the other two thirds.

The objections to teaching reproduction in the Health classes are (1) that the Health classes already have sufficient material to cover in a limited time, and (2) that their course concerns humans only rather than being a comparative study. Actually we teach nothing about human reproduction, but apparently this student saw the connection between frogs, rabbits and humans.

The other recommendations in the subject matter field can be discussed more briefly. While outside speakers have been used in the past, it is asking a great deal to ask of a person that he come and talk to two or three classes a period for six periods. The wish for more plant and animal identification is a little ambiguous. Did the student mean more use of the classification keys or more study of actual specimens? The last recommendation, that for more illustrations in the text was not a very valid criticism as the text contains more illustrations than most biology texts,

over half the book being given over to pictures and diagrams.

The group of students commenting on the workbooks which accompany the text was smaller than the preceding group. One liked using a workbook, two would have preferred to spend less time on workbooks and one saw no use in workbooks.

Of the four students criticizing tests, two preferred the tests Mr. Oliver gave to the printed ones, one wanted "the printed tests junked and more home-made ones used," and a fourth recommened more short tests on daily work to determine whether the assignment was understood. The "home-made" tests were tests Mr. Oliver and I both gave, for which we told students ahead of time what would be asked. They were meant to supplement and not to replace the printed tests. The use of frequent short tests for diagnostic purposes is also good. One difficulty with this is that a different test must be used in each class. Also it is very possible that time spent grading many tests might better be spent working out demonstrations, setting up experiments, and getting frequent changes of interesting material onto the bulletin boards.

Four students made comments on course organization. Of these, one thought that classes for boys and girls should be separate, one thought Biology should be a Senior rather than a Sophomore subject, one thought classes should contain about twenty students instead of thirty-six, and one thought the course should be required. The last recommendation was an interesting one to find expressed by a student. According to Washington state law, a year of science is required, but the student is free to choose the science. Judging from the number of Biology classes, most do take Biology.

Sixteen students liked films and found them helpful. Of those six recommended the use of more films, one thought there should be two or three films per unit, and one hoped we could get more of the Walt Disney films as they were easier to remember. One student expressed her feelings this way. "Since I remember better the things I see than the things I hear and read about, I liked the movies best in the course. I also liked seeing the torso and the way it is put together, and the eye and ear models were also very interesting."

Among the students there were forty-six requests for first hand study of life forms and for projects. It was in this group of suggestions that I found myself agreeing more with Mr. Oliver's students as to some of the weaknesses of the present course. Perhaps for that reason, it was in this section that I found comments and suggestions most helpful.

Since the fifty-five recommendations made by these forty-six students are rather numerous, it may be simpler to list them first and to discuss them afterwards. Eleven points were brought out, some of them rather closely related.

1. More field trips	16	requests
2. More experiments or laboratory work	18	"
3. More demonstrations	1	"
4. More study of specimens	1	"
5. More study of living things	1	"
6. More use of the microscope	5	"
7. Dissections—plant and animal	9	"
8. Special projects for the class	1	"
9. Plant collections	1	"
10. More research and outside work	1	"
11. One week out of ten set aside for individual projects such as work with microscopes, field trips and written reports	1	"

Field trips are a definite need and also a problem. Our classes are rather large for efficient handling by one teacher. On the other hand, I found in a summer school class which was an above-average group scholastically that no one could name even two of the local wild flowers. In a nearby park, they not only did not know the more common trees but could not name flowers like petunias and sweet alyssum. If other classes are simular, there should be some definite field trips planned.

Recommendations Two through Five are somewhat allied and are rather a large

order as things are. Speaking for myself, I usually need more than my one free period for work on the Visual Education Program. Consequently, while in theory I agree that there should be quite a few demonstrations and experiments, adding very many to the course will have to wait until more pressing changes are worked out and incorporated into the course.

While only five students thought there should be more use of microscopes, they were pointing out a definite weakness in the course. There were three reasons why I myself used microscopes less last year than the preceding year: (1) high breakage rate when prepared slides were used, (2) lack of time in a period for adequately instructing and helping students, and (3) lack of time in the semester for any large amount of microscope work. This year I tried using microscopes at the front of the room and setting up one slide of a kind. Breakage was eliminated, but students, conscious of others waiting behind them, looked too briefly and were unable to explain what they saw.

The apparatus which I hope will provide a solution is the micro-projector ordered this spring. With that, the whole class can look at one slide and have the important features pointed out and explained. In the case of slides of complicated structures like stems, comparisons can be made to the Jurica charts and to the illustrations in their books. This work should also be of assistance to students themselves when they work with microscopes. Having seen clearly focussed slides, they will know when their own microscopes are poorly adjusted. Also they will have more of an idea about interpretation of what they see.

On the question of dissections students feel strongly, either wanting them or being much opposed. Personally I have never cared much for animal dissection in high school classes. If animals are to be dissected, the dissection must be competently done and flippant or callous attitudes must be avoided. Since we do not have time to teach skill in dissection, most students would dissect badly and have no clear idea of what they found. Also many would have to fight a feeling of revulsion which we lack time to help them overcome. As substitutes, charts, models, movies, and study of the torso are quite effective for most. One can learn more about relationships of organs and about mechanics of respiration and circulation from a fifteen or twenty minute demonstration of the torso than from several days cutting up a frog and trying to discover those same things. The feeling of revulsion should be less too, although one or two students faint every year during torso demonstrations.

Possibly dissections should be an individual rather than a class project. In the past I have not refused students who wished to bring their own specimens for dissection, though I have discouraged them to some extent by saying that they may have to work on it after school. In most cases that ends the matter, but if a student is really interested enough to work after school, I find time to help him.

Considering the last four suggestions, which concerned projects and collections, we do not have time as the course is now organized for projects in class time, and most students are unwilling to spend much outside time on them. The suggestion that one week out of ten be spent on individual projects is an attractive and definite one. This idea might be worked out if it were combined with another--the elimination of workbooks. While workbooks may have a definite usefulness in Physics or Chemistry, I have never been convinced of their value in Biology. Students think that if they copy into their workbooks what they can find in their books or in other students' workbooks, they have done their lesson, and that it should not then be necessary for them to learn it also. The chief advantage of workbooks is that on workbook days the teacher has a little time for setting up microscopes and preparing experiments. A

year without workbooks but with projects would have to be carefully planned.

As indicated in the foregoing discussion, many of these students recommendations cover changes which we as teachers would like to see made in our present Biology course. If nothing else, they are valuable as a starting point in consideration of changes to be made next year and in following years. Unfortunately the time we have for class preparation is very limited, and the changes which can be made in any one year are consequently also limited.

THE PRESENT STATUS OF GENERAL OBJECTIVES IN THE TEACHING OF SECONDARY BIOLOGY*

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Every high school teacher realizes the importance of the use of objectives in guiding learning, but a study of the objectives of biology for general education as set forth in high school textbooks, courses of study, and professional literature reveals that these objectives are numerous and varied. The question inevitably arises, "Which of these objectives have the greatest educational value?" The attempts that have been made in the past to determine which aims should have precedence over others have been difficult indeed, although seemingly well worth the attempt since it is obviously impossible to stress a great number of aims in any one course and only the most worthwhile should receive emphasis.

The purposes of the present investigation were to determine; (1) the relative values of the general objectives in the teaching of secondary biology for general education by a survey of the literature of acknowledged authorities and (2) what changes have taken place in the teaching of biology in the last twenty years by a comparison of the objectives for the period 1926-1935 with those for the period 1936-1945.

Part of the difficulty in an analysis of aims lies in the fact that they vary in generality from such broad statements as, "To make the student a good citizen", to such specific statements as, "To provide a knowledge of the life cycle of the Anopheles mosquito". The writer believes that an analysis of general objectives of biological study is more desirable than a comparable study of specific objectives. There are many justifications for such a belief. First, they are less numerous than specific objectives; second, they contribute directly to the general aims of education. The more specific objectives, on the contrary, are directed to the achievement of one or more of the general objectives and tend to give less organization to an entire course than do a few general objectives.

ANALYSIS OF OBJECTIVES

Although an analysis of some one hundred and fifty sources was made for the present study, many were rejected on the grounds that they did not mention general objectives, that they were not on the secondary level, that they were not concerned with biology for general education, and that they were not published in the United States between 1926 and 1945. Twenty-seven sources in all were found to contain suitable statements for the period 1926 to 1935 and the same number of sources for the period 1936 to 1945.

All statements of objectives from a given source were transferred to a card which indicated the author and title of the

*Based on a thesis submitted in partial fulfillment for the M.S. degree at the University of Pittsburgh.

article or book. Each source was treated in the same way.

An analysis of the cards thus prepared indicated that most of the statements could be classified under one of the following objectives:

(1) The study of biology should develop in the pupil a proficiency in the use of the scientific method.

(2) The study of biology should create certain desirable scientific attitudes in the pupil.

(3) The study of biology should equip the pupil with a knowledge of biological facts and principles.

(4) The study of biology should increase the pupil's interest in living things.

(5) The study of biology should enable a pupil to make proper social (home, school, and community) adjustments.

(6) The study of biology should have certain economic value for the pupil.

(7) The study of biology should enable a pupil to make wise vocational selections.

(8) The study of biology should help a pupil make better use of leisure time.

(9) The biology course should prepare a pupil for future study or a career.

(10) The study of biology should direct a pupil to more healthful living.

(11) The study of biology should make life more enjoyable and more meaningful.

(12) The study of biology should develop a more ethical character.

The objectives on each card were then marked with a number to indicate to which objective group they belonged. When all of the cards had been so marked, these objectives were then listed according to the groups into which they fitted on what could be called a collection sheet.

These general categories of objectives were obviously of two types. The first four, those dealing with the scientific method, the scientific attitude, knowledge, and interest, contribute to those other objectives dealing with social adjustment, vocational direction, the use of leisure time, and the like, which are desirable life outcomes. The first four can be called intellectual objectives; the rest, practical objectives.

The results of this analysis are to be

TABLE I

FREQUENCY OF MENTION OF OBJECTIVES IN GENERAL BIOLOGY

Groups of Objectives	A. *Total Mention* 1926-35	1936-45	B. *% of Mention* 1926-35	1936-45	C. *Alteration to Present*
INTELLECTUAL					
I. Scientific method	30	23	14%	10%	—4
II. Scientific attitude	14	15	7%	7%	0
III. Knowledge	50	44	24%	20%	—4
IV. Interest	11	16	5%	7%	2
TOTAL	105	98	50%	44%	—6
PRACTICAL					
V. Social	9	16	4%	7%	3
VI. Economic	18	28	9%	13%	4
VII. Vocational direction	4	2	2%	4%	2
VIII. Avocational direction	7	12	3%	5%	2
IX. Preparation for future work and study	8	6	4%	3%	—1
X. Health	19	19	9%	8%	—1
XI. Aesthetic	11	9	5%	4%	—1
XII. Character training	7		3%		—3
XIII. General application	17	22	8%	10%	2
XIV. Miscellaneous application	5	4	2%	2%	0
TOTAL	95	124	49%	56%	+7

found in the two Tables which follow. Table I gives the frequency of mention of each type of objective included in the study. Column A, Table I, shows the total number of mentions of objectives in each category for the two periods under survey, the left column representing the earlier period and the column to the right, the later. Column B in the same Table indicates the percentage of mention of the same objectives for the identical periods. In column C is indicated the total alteration to the present of the second period over the first period, a minus quantity representing a decrease in frequency for a given type or objective and a positive number showing a greater frequency.

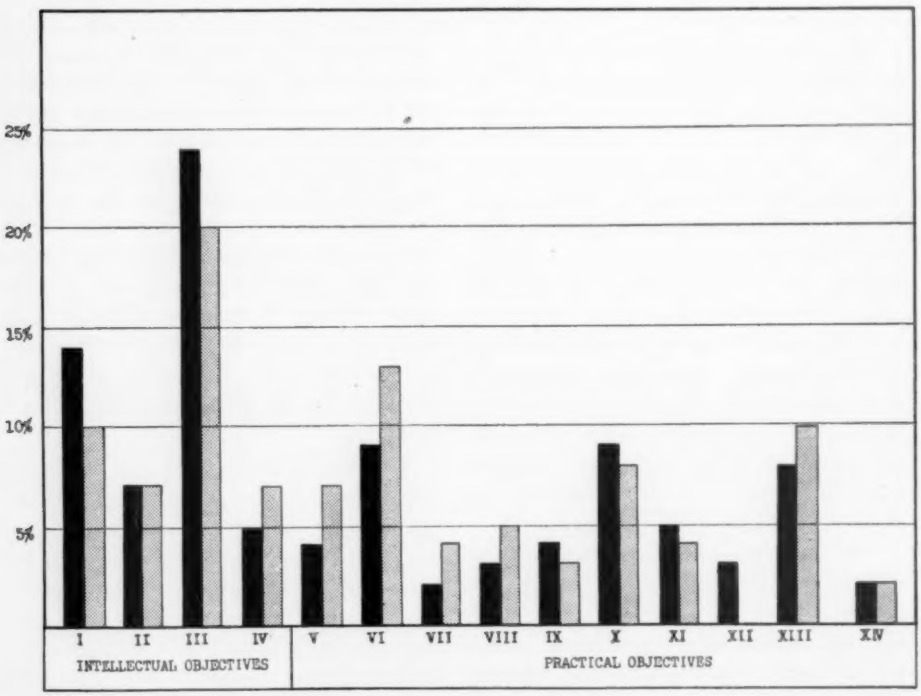
Table II demonstrates more graphically than does Table I the relative importance in the opinion of educators of the various objectives in the teaching of biology for general education. The first column in each pair is an index of the percentage of mention for the years 1926-1935; likewise, the second column in the pair for the years 1936-1945.

The practical objectives stemming from the social legislation of the 1910s in the form of child labor laws and compulsory school attendance laws are evidently still the dominant objectives in the teaching of biology in the opinion of authorities. There has been, in fact, in the twenty year period of the present study an increase of eighty-seven percent in practical objectives over the intellectual objectives. From this it can only be concluded that the teaching of biology in secondary schools should follow practical lines.

In the opinion of a majority of the au-

TABLE II

GRAPHICAL COMPARISON OF CHANGE OF EMPHASIS ON OBJECTIVES IN GENERAL BIOLOGY (PERCENTAGE OF MENTION)



thorities, the intellectual objectives were not aims in themselves but only means to the fulfillment of other, more practical, objectives. For example, even though the practice of the scientific method and knowledge ranked high as objectives in their own rights, in most cases it was obviously the idea of the educator that they should be developed so as to contribute the utmost to one or more of the practical objectives, such as health or enjoyment of leisure time.

Interest objectives, showing an increase of seventy-one percent in the two periods under study, are the only group of intellectual objectives which have gained in importance in the estimation of the authorities. Undoubtly the reason for this increase in an intellectual objective, while other intellectual are remaining stationary or declining, is related to the reason for the increase in the case of the majority of the practical objectives; namely, that when a pupil is aware that an outcome is of practical value to him it often follows that he will be interested in it.

The greatest total increase in frequency of mention among the practical aims was found in the category referring to the economic values of biological study. The reasons for this are several: first, the great economic depression in the United States brought to educators the realization that each subject in the curriculum, including biology, should have some dollars-and-cents value to the pupil, secondly, a demand on the part of the adult public for education that would enable their children to save money and to put to good use the things that they did have (the writer can remember planning lowcost, nutritious meals in high school), and thirdly, the use of conservation as a political issue.

The practical objectives showing the second greatest increase, those dealing with social adjustment also arose from a sense of need. Due to the immigration of southern European elements into areas containing an older northern European stock, a need for mutual understanding and a knowledge of how individuals of different races might get along arose. There have long been myths about so-called racial superiority stirring up trouble in areas of mixed population and to combat this reliable information about the different races of man was needed. The biology classroom, the logical setting for the discussion and solution of problems of any nature arising from the association in social groups of living human organisms, seemed the most suitable place to settle this type of problem.

As the result of minimum-hour labor laws, the amount of leisure time of the general population was greatly augmented. From this emanates the problem of the use of leisure time to greatest advantage. The results of the present study indicate that the biology course should offer a survey of hobbies and an opportunity for pupils to develop worthwhile pastimes to occupy their leisure.

A comparison of the results of the survey of vocational objectives and those objectives dealing with biology as preparation for future work and study indicates that as the former group increased in frequency of mention the latter decreased. One educational philosophy may be the root of these two seemingly opposite trends. This is the theory that the tenth year in school is the natural level for a survey of vocations with the purpose of deciding upon the type of career best suited to the interests and aptitudes of the pupil rather than the level for the actual preparation for a life work.

It is the belief of the writer that there was a lower frequency of health and aesthetic value objectives, not because good health and happiness were considered less important in the later period but because the other practical objectives were proportionately more numerous in that period.

The general application of biology to

life problems of all types has been mentioned with increasing regularity because of a growing realization of the fact that there is no other subject in the curriculum which touches upon man's affairs at so many points and has within its scope the solution of so many problems which perplex us. That biology is becoming a required subject in more and more schools is indicative in itself of the value of biology in the opinion of administrators. So biology, taught more and more along the lines of a practical and social as well as a natural science, can, in the future, be expected to have greater value to the individual and to society at large.

THE INDIVIDUAL LABORATORY METHOD COMPARED WITH THE LECTURE-DEMONSTRATION METHOD IN TEACHING GENERAL BIOLOGY*

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I

THIS research work was carried on during the school year of 1940-1941 in the Whitesboro Central School, Whitesboro, New York, and was performed with two groups of secondary school students whose General Biology courses ran parallel throughout the year. At the beginning of the school year of 1940-1941 there were two exceptionally large sections of General Biology. Because of size of these sections, it was found expedient to divide these two groups into three smaller ones of twenty-five students each. It was decided that an attempt should be made to divide these groups in such a manner that two of them should be as nearly equated as possible on the basis of Intelligence Quotient obtained by the previous administration of Kuhlman-Anderson Intelligence Test, and also on the basis of their age levels and sex. It was with these two groups that the study was made to compare achievement using different types of laboratory as the variable factor.

Later in the semester, the Otis Self-Administering Test of Mental Ability, the Higher Examination: Form A, was administered to these students as a check on the Kuhlman-Anderson Intelligence Test. It was found that the two classes were equated within the probable error of the Otis test which is ± 3.

TABLE I
COMPARISON OF I. Q. SCORES OF THE TWO GROUPS ON THE OTIS TEST

Comparison	*Individual Laboratory Group*	*Lecture-Demonstration Group*
Range	94-132	96-127
Mean	108.8	109.8
Median	110.0	107
Standard Deviation	9.95	8.38

Table I indicates that these two groups are equated on the basis of Intelligence Quotient closely enough, so that the intelligence of the students as measured by the Otis test is not likely to be the variable factor.

TABLE II
COMPARISON OF THE AGE LEVELS OF THE TWO GROUPS TESTED

Comparison	*Individual Laboratory Group*	*Lecture-Demonstration Group*
Range	15 yrs. 1 mo.-17 yrs. 9 mos.	13 yrs. 7 mos.-18 yrs. 6 mos.
Mean	16 yrs. 1 mo.	16 yrs. 4 mos.
Median	16 yrs. 0 mo.	16 yrs. 1 mo.
Standard Deviation	8.75 mos.	1 yr. 2.5 mos.

On the basis of mean and median ages the two groups are well matched. There

*Based on a thesis submitted in partial fulfillment for the M A. degree at the New York State College for Teachers, Albany, New York, 1942.

apparently is a much greater range of age in the lecture-demonstration group, but excepting the case of the lower limit of 13 years 7 months and the case of the upper limit of 18 years 6 months, all of the other cases in this group fall within the age range of the individual laboratory group. In addition, the ratio of girls to boys in the individual laboratory group was 13-12 while in the lecture-demonstration group the ratio was 14-11.

Examination of these two groups will show that they have been equated upon these three bases as well as was possible under the natural limitations. There is no significant difference between the groups relative to age, sex or mental ability, therefore it can be reasonably assumed that the two groups are fairly similar. One limitation to such an assumption would be the fact that no account was taken of any results which might have been obtained upon a pretest concerning the students' previous experience with subject matter materials relative to General Biology. In any case, the only previous scholastic experience that any of the students in either group had with science was with the regular Ninth Year General Science course which had been taken by each one as a required Ninth Year subject. Instruction in this course was given by the same teacher within a three year time span, using the same textbooks and workbooks for all of the students.

At the beginning of the school year in 1940-1941, a list of experiments were compiled, all suggested as laboratory exercises for a General Biology course by various sources. From this list were selected those experiments which could be used most feasibly as either a lecture-demonstration or as an individual laboratory project. Again from this second list were selected thirty-five experiments which should provide, to the best advantage, a well-balanced laboratory program for a year's work covering all the units comprising the General Biology syllabus. These thirty-five experiments (see Appendix) were organized in two different manners. One set was written up as a teacher's manual for presentation as lecture-demonstrations by the teacher, while the other set was written up as individual laboratory exercises to be used by each student.

From the beginning of the school year, the two groups of students were instructed in a manner as much alike as was possible. Each group used the same material in the syllabus and the same method of presentation was used from day to day. They had the same tests and the laboratory day was the same for each group from week to week. At no time was one group advanced two days ahead of the other in its instruction. When such a situation arose, the class in advance was slightly delayed so that the other group might again be brought to parallel study. The lecture-demonstration group received laboratory work the last period in the morning session, while the individual laboratory group performed its exercises the last period in the afternoon session. Each student was expected at the end of each laboratory period to make a write-up of the work performed and to indicate the techniques used and the conclusions reached. At the end of the year these write-ups were compiled by the student into an indexed notebook and filed for a period of six months.

The first test to measure achievement was administered to these two groups the first week in June. This test was the New York State Regents Examination in General Biology, which was prepared for the January 21, 1941 examination. The students were totally unaware that any test was to be given and, since these tests are not available in any review book until the following school year, they were unfamiliar with the test material. Since none of the students had taken this examination, no access could have been possibly had to it.

The New York State Regents Examin-

ation in General Biology, for both January and June, is divided into three parts. The first part consists of fifty short answer questions while the second and third parts are questions involving explanations of which the student has a choice of five out of eight questions. The first part was given the first Monday in June after the course had been completed, and the second and third parts were given the next day. The time allowed each day was one full hour.

The second achievement test administered to the two groups was the New York State Regents Examination in General Biology prepared for June 17, 1941. Since this test was available to no one until this date, there was no access to this examination whatsoever. One reason for the administration of the two tests was the improbability that all students would elect to take the New York State Regents Examination, but instead choose the local final examination to merely obtain school credit for the course. In such a situation a number of students would have no identical examinations for June 1941 with which to validly compare results.

A second reason for the administration of two tests was the possibility of having two bases for comparing results. The first test provides a comparison of achievement on an examination for which there had been no preparation, the second provides a comparison on an examination for which all had opportunity to prepare.

TABLE III

RESULTS OBTAINED ON THE FIRST ACHIEVEMENT TEST

Comparison	*Individual Laboratory Group*	*Lecture-Demonstration Group*	$\frac{\textit{Diff.}}{\textit{S.D. Diff.}}$
Range	44-97	43-87	——
Mean	71.4	67.1	1.2
Median	75	67	1.6
Standard Deviation	14.7	13.02	——

II

The results obtained by the two groups on the first examination are compiled in Table III and the results obtained by the two groups on the second examination are compiled in Table IV.

TABLE IV

RESULTS OBTAINED ON THE SECOND ACHIEVEMENT TEST

Comparison	*Individual Laboratory Group*	*Lecture-Demonstration Group*	$\frac{\textit{Diff.}}{\textit{S.D. Diff.}}$
Range	63-96	56-93	——
Mean	77.2	72.1	1.7
Median	76	66	2.7
Standard Deviation	10.9	11.52	——

The measure used in the last column, $\frac{\text{Diff.}}{\text{S.D. Diff.}}$ represents the difference between the mean or median divided by the standard deviation of the differences of the raw scores from the mean or median of the scores. It is from this formula that the reliability of the difference between the mean and median scores may be inferred.

III

An evaluation of the results obtained from applying the criterion, $\frac{\text{Diff.}}{\text{S.D. Diff.}}$, show that no conclusive results can be drawn as to the relative merit of either one of the methods of laboratory presentation over the other on the basis of scores obtained on the New York State Regents Examinations in General Biology given in 1941, for if any statistical significance is to be inferred, the results obtained from application of the aforementioned criterion should equal or exceed 3.

However, if the number of students in each of the groups had been increased from twenty-five to fifty, and their scores had been dispersed throughout their representative groups within the same range, then the differences between the mean and median scores would have been statistically significant.

The conclusions which may be drawn are as follows:

1. The results indicate that the individual laboratory shows a slight trend toward the better preparation of the students for the General Biology Regents than does the lecture-demonstration method. There is a difference of 4.3 points and 5.1 points between the mean scores obtained on the two achievement tests in favor of the individual laboratory, and also a difference of 8 points and 10 points between the median scores obtained on the two achievement tests, also in favor of the individual laboratory. All the students who elected to take Regents Examinations in the individual laboratory group equalled or exceeded the passing score on the June Regents, while there were two failures in the lecture-demonstration group. Although there may be a trend in the scores showing the greater value of the individual laboratory, this difference can in no way be deemed conclusive.

2. The following recommendations should be followed in future studies in this field:

A. Pupil groups should be equated not only on the basis of age, sex and Intelligence Quotients, but also by results on a pretest measuring previous knowledge of subject matter materials in General Biology.

B. Groups should be made as large as conveniently possible so that any difference occurring between the mean and median scores obtained on achievement tests measuring the results of experiment may be more mathematically significant.

C. The experiment should be carried on jointly by many schools using identical programs of laboratory. In this way any results obtained would be based upon composite results of many and varied communities and thus would finally offer a more definite answer to the problem as to which is the superior type of laboratory program for General Biology.

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APPENDIX

Laboratory exercises used in the foregoing study:

I. To study methods of classifying stocks of mankind.
II. To study basic plant and animal structure.
III. To study systems of classifying plants and animals.
IV. To study organ systems in animals.
V. To study the cross-section of structures in the plant stem.
VI. To study the relation of the root to plants.
VII. To study cells and tissues.
VIII. To study simple animals and their structures.
IX. To study simple plants and their structures.
X. To study the structure of the eye.
XI. To study the structure of the brain.
XII. To study egg formation in animals.

XIII. To study variation among members of a species.
XIV. To study different types of asexual reproduction.
XV. To study different types of sexual reproduction.
XVI. To study the rules of inheritance.
XVII. To investigate sex ratios.
XVIII. To study the structures in a plant seed.
XIX. To study the parts and uses of the parts of a flower.
XX. To study the effect of preservatives on bacterial growth.
XXI. To study the effect of heat on bacterial growth.
XXII. To study the effect of environmental factors on bacterial growth.
XXIII. To study the prevalence of bacteria in body liquids.
XXIV. To study and test for carbohydrates.
XXV. To study and test for fats.
XXVI. To study and test for proteins.
XXVII. To study the effect of salivary secretions on starch.
XXVIII. To study the effect of gastric secretions on protein.
XXIX. To study the effect of bile salts on fat.
XXX. To study the functions of the respiratory system.
XXXI. To study the reactions of the nervous system.
XXXII. To study the parts of the blood stream.
XXXIII. To study the action of the muscles in the arm.
XXXIV. To study various insect pests.
XXXV. To study methods of plant improvement.

THE CENTENARY OF THE BRITISH CHEMICAL SOCIETY

James Langham

"Twenty-five gentlemen," we are told, "who were interested in the prosecution of chemistry, met together on the 23rd of February, 1841, and formed a Chemical Society."

That statement as it stands may not appear to be a matter of international importance; but, as it happens, that is precisely what it is, and that is one of the reasons why the Society's Centenary Celebrations to be held in London in July 1947 will attract world-wide attention. The recent world war must be blamed for the postponment of the celebrations until 1947.

A centenary of a birth or death, of the foundations of a Company, Corporation or Society, may have an interest only for those few who are in some degree personally concerned with an individual or undertaking. But as we shall find, the British Chemical Society's centenary should be of considerable interest to many, for had it not been for some of the early discoveries of this great organization, many of the facilities which we enjoy today might still be lacking.

But let us return for a moment to those "twenty-five gentlemen" who made this momentous decision over a hundred years ago. What had they achieved? They had founded the first Society formed solely for the study of chemistry, and by providing information and opportunties for research, they were the first men to bring lasting benefits to this branch of science.

The first President to be elected was Thomas Graham, the most distinguished chemist of his time, and the first Secretary, who had organized the original meeting, was Robert Warington. They were the leaders of the new Society, and to this day there exists a constant reminder of their importance in the world of chemistry. Whenever a new Fellow is admitted to the Society, he signs his name in what is called the 'Obligation Book', now over a hundred years old; and if he looks at the first two signatures he will see the names of Thomas Graham and Robert Warington.

Those gentlemen signed their names as members of a small, unknown Society in 1841. In 1946, there are over six thousand Fellows. The aim of the society has not changed. It is still devoted to the study of chemistry as a whole rather than concerned with the professional and industrial aspects of the science alone. These branches of chemistry have grown and developed as

'offshoots' of the parent Society. The Royal Institute of Chemistry, founded in 1877, now devotes itself to the professional affairs of chemists, while the industrial side is the concern of the Society of Chemical Industry which was founded four years later. Other societies came into being for specialized purposes, and today representatives from all of them form part of what is called the Chemical Council, which in Britian provides assistance in publishing chemical information and the results of research.

The Chemical Society may well be proud of its history. It is impossible in a short account to enumerate all the many instances of benefits to mankind from the discoveries made by Fellows of the early days. But we can at least cite a few of their major achievements.

For example, the way in which the research chemist may have a profound influence on social and economic development is shown in the discovery of aniline mauve dye by W. H. Perkin, one of the original presidents of the Society. This led to the development of the whole of the coal tar industry as it is today, embracing dyestuffs manufacture, synthetic medicinals, the photographic industry and much else.

Gilbert and Lawes, two other famous chemists, studied plant life to such good purpose that we are now able to use synthetic fertilizer for the production of food.

And here are three other famous names in the chemical world—Crooks, Dewar and Ramsay, all past presidents of the Chemical Society. Crooks was the pioneer of cathode ray tube, now used in television. Dewar's experiments in low temperature produced, as one example, the familiar thermos flask, while Ramsay's discovery of the rare gases had numerous useful results, including the neon display signs so frequently seen today in the peace-time town life of many countries.

It was stated earlier that the Chemical Society is of international importance. Let us see how this will apply to the forthcoming Centenary. The Society has always been the model for similar societies set up in other countries, and in 1938 it was decided in Rome by the International Union of Pure and Applied Chemistry to hold its next International Congress in London at the time of the Chemical Society's Centenary.

In spite of all the political and other complications that a world war involves, none the less the Rome decision of 1938 will duly be carried out, and after the Centenary celebrations from July 15th to July 17th 1947, the eleventh International Congress will take place in London.

The celebrations themselves will be of historical importance and interest. Distinguished delegates will include the Honorary Fellows of the Society, among whom are the worlds greatest chemists of today. One of them will be invited to follow in the succession of great personalities of the past by becoming the Society's Faraday Lecturer. The Lectureship was founded in 1867 to commemorate the name of Michael Faraday who was elected a Fellow of the Society in 1842 and was one of its vice-presidents.

There will be a centenary address and a formal ceremony for the presentation of addresses. A number of scientific lectures are scheduled, also visits to places of interest in the London area; and an exhibition is to be held at the Kensington Science Museum in London during the period of the celebrations and the International Congress.

Those three days of July this year will be long remembered, not only by the many distinguished chemists who will be present, but by all who take an interest in the progress of a great science.

RECENTLY ELECTED OFFICERS OF NARST AND NCES

National Association for Research in Science Teaching

President: Ira C. Davis, University of Wisconsin, Madison, Wisconsin.
Vice-President: Joe Young West, State Teachers College, Towson, Maryland.
Secretary-Treasurer: Clarence M. Pruitt, Oklahoma A and M College, Stillwater, Oklahoma.
Executive Committee: Earl R. Glenn, State Teachers College, Montclair, New Jersey.
Executive Committee: N. E. Bingham, Northwestern University, Evanston, Illinois.

National Council of Elementary Science

President: George Haupt, State Teachers College, Glassboro, New Jersey.
Vice-President: Rose Lammel, Teachers College, Columbia University, New York, New York.
Secretary-Treasurer: Glenn O. Blough, U. S. Office of Education, Washington, D. C.

BOARD OF DIRECTORS AND THEIR TERMS

Clarence M. Pruitt (1947–1952)
Oklahoma A and M College
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Minneapolis Public Schools
Minneapolis, Minnesota

Gerald S. Craig (1947–1949)
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New York, New York

Louise Neal (1947–1948)
Colorado State College of Education
Greeley, Colorado

BOOK REVIEWS

Powers, Samuel Ralph; Neuner, Elsie Flint; Bruner, Herbert Bascom; and Bradley, John Hodgdon. *Adventuring in Science* series: I. *Exploring Our World.* 522 p. $1.44. II. *Our World Changes.* 585 p. $1.68. III. *Using Our World.* 666 p. $2.16. *Our World and Science.* 684 p. $2.20. *Directing Activities:* I. 120 p. $0.64; II. 166 p. $0.68; III. 166 p. $0.72; combined vol. 266 p. $0.96. Tests and Teachers' Manual for each are available. Boston: Ginn and Company, 1946.

This set of books, revised five years after the earlier edition (1941), is designed for use in General Science courses. The first three are for use in grades VII, VIII, and IX where there is a sequence in science; the fourth is "a single volume General Science course for the ninth year." The latter includes much of the material in the other three. The authors are well-known in the field of science education.

These textbooks have received great attention as to up-to-date factual, information, presentation in a style attractive to youth, and application to everyday life situations. The authors set themselves a difficult goal, "to avoid both confusion and condescension," and seem to have achieved it to a remarkable degree.

Numerous appropriate and eye-catching illustrations include photographs, maps, drawings, cut-away diagrams, graphs, and charts, which clarify the adjoining text matter. There are many suggestions of things for the students to do: examine illustrations, collect specimens, observe familiar objects, perform simple experiments, books to read, "correct these statements," glossary of scientific terms, and the like. "No pupil is expected to attempt all the activities provided."

In a note to the teacher, the Thirty-first Yearbook is quoted, "In the classroom it becomes his (the teacher's) duty to direct, to motivate, and to supervise the learning activities; to provide other sources; to measure the learning products; and to instill the desire for the continuance of learning. It should be understood here that the learning products to be sought are not primarily the acquisitions of information, but rather modified adjustments in individual and social life." Unless the teacher understands and accepts this point of view, any textbook may serve as a means for overemphasis on factual material. Any teacher who has the vision would find these textbooks usable in avoiding such pitfalls.

There is one mannerism, quite widespread in school textbooks and notebooks, used in this series, which the present reviewer would like to see abandoned by science teachers. And that is the questionable use of the word *PROVE.* Nowadays there is the prevalent misconception, among many regarding science, that experiments in scientific research are to *prove* this or that to be true, rather than to discover what the facts are. We hear repeatedly in radio and other advertising that, "Science has *proved*" a certain cigarette is less rasping to the windpipe or "Science *proves*" such and such a mouth wash kills more germs and so on *ad nauseam.*

It seems to me that science teachers and writers of science texts are responsible for correcting these misconceptions, rather than falling into the same error themselves! If science means

anything—it means change—rather than finality. This is indicated in the titles above. It is about time for the word PROVE to be relegated to formal logic and mathematics, where it belongs! There are so many synonyms that are much more suitable: verify, substantiate, confirm, convince, corroborate, support, attest, authenticate, and the like. Similarly *evidence,* rather than *proof.* Examples of the dubious practice are to be found, for instance, in the labels under illustrations in *Our World and Science,* pp. 94, 139, ("Through these experiments you can prove that air occupies space.") 140, 151, 157, 287, etc. How much better is the wording under similar illustrations on pp. 87, 91, 144, 147, 153, 154, 294,—where such words as 'determining,' 'finding,' 'demonstrating,' 'show,' and 'studying' are used!

After all, the real value of a textbook is its appeal to pupils. (See, "The Trouble with Textbooks," Chap. XVII, in *The Art of Plain Talk,* by Rudolph Flesch, Harper, 1946.) The way to find out whether it is unreadable to the ones for whom it is intended is to let them try it. The books in this series have withstood the test.

—M. E. O.

CRAIG, GERALD S. AND HYDE, MARGARET O. *New Ideas in Science.* Boston: Ginn and Company, 1946. 377 p. $1.44.

This member of *Our World of Science* is for Grade 6. I cannot think of a boy or girl who would not be intensely interested to read and reread this book. In so doing he would be learning the basic facts in science. It treats molecules and matters, our neighbors in the heavens, life in the ocean, simple electricity, air travel, useful facts about light, sound and water. Making, losing and saving soil are all treated in an interesting way.

All topics are beautifully illustrated in black and white and in color pictures. The stories are all well told. Questions and suggested activities will stimulate many of the boys and girls to do outside reading and experimenting.

—W. G. W.

HURD, ARCHER WILLIS. *What the Testing Program in the Schools of Nursing Has Taught Us.* Bureau of Educational Research and Service, Medical College of Virginia, Richmond, Va., January, 1946.

This publication by some nine members of the School of Nursing of the Medical College of Virginia is the second to grow out of a five-year study of the curriculum in the schools of nursing. This brochure aims to bring up to date the research done in this field of education at the college and other colleges and universities which were visited in 1944 and 1945, extending from Toronto, Canada to Birmingham, Alabama. In addition, more than 100 administrators in schools of nursing throughout the country lent their assistance through questionnaires. This research program was based primarily on (1) adopting a major aim for the basic curriculum, (2) planning an ideal educational blue-print to accomplish this aim or objective, (3) testing the blue-print, (4) evaluating testing data, (5) basing further proof of further changes on satisfactory student achievement. Knowledge areas were studied, and skills and techniques were also considered. Personality characteristics were analyzed and a list of 45 characteristics prepared. The composite examination for nurses is carefully investigated and scored and recommendations made on the basis of the testing program. An excellent bibliography accompanies the brochure.

—G. O.

HURD, ARCHER WILLIS. *Building a Curriculum for Professional Schools With Special Reference to Nursing.* Bureau of Educational Research and Service, Medical College of Virginia, Richmond, Virginia, August, 1946.

Doctor Hurd presents here additional material based upon his studies of the basic curriculum in nursing extending from Canada to Birmingham, Alabama. Emphasis in this study is based upon the core of science (physical and biological) content basic to the practice of nursing although the total program is considered. Some of the

areas considered, as revealed by the contents, are: Premises for a Curriculum project; blueprint for a proposed skeleton Undergraduate Program; major areas in basic training; organization of courses; integrated knowledge courses in nursing education; a suggested course in the First Year of the Curriculum for Nurses; nursing arts and skills; criteria for teaching and judging a unit of teaching; samples of curricula; analysis of data from leading nursing schools; a suggested three-year curriculum; summary of questionnaires. Such a comprehensive study as this ought to stimulate curriculum revision and better curricula in schools of nursing.

—G. O.

METZNER, JEROME. *Science Experiences* and *St. James Park, Bronx, New York, as an Outdoor Laboratory for the Teaching of Science in Nearby Schools.* New York: Jerome Metzner, Junior High School 115, 1946. 56 p.; 20 p.

These two publications are quite detailed, specific and down-to-earth (literally and figuratively) in content. They constitute the preliminary report of a Science Curriculum Research Project in the public schools of New York City. This project is an important beginning which, it is hoped, is to become a city-wide program for a twelve-year sequence in science. The State of New York has had a well-planned curriculum in Elementary Science for at least two decades, for which there is no counterpart as yet in New York City; the project here reported is an excellent approach.

The first of the above booklets consists of a challenging introduction: Suggested Procedures for incorporating science experiences in teaching practice; a record of science experiences of children in three levels: Kindergarten–Second Grade, Third and Fourth, and Fifth and Sixth Grades, with illustrations (drawings), descriptions of excursions, lesson plans, objects displayed in the science corner, special interests of individuals, objectives and outcomes; a list of services and materials available to the teacher in providing science experiences in the classroom; collaboration with the Bronx High School of Science; and plans for the current year.

The second booklet is a careful report on "a type environmental study pointing out the resources of a natural area for science-teaching purposes." Included are a map of St. James Park; suggested techniques for field excursions;

detailed analysis of the resources found in this park; in implications for learning in areas other than science, and a selected bibliography.

Anyone interested in science education will find these publications useful, rich in suggestions for planning similar work.

—M. E. O.

GRUENBERG, BENJAMIN C., SNYDER, EMILY EVELETH, AND MILLER, JESSE V. *A Workbook for Students of Biology.* Boston: Ginn and Company, 1946. 267 p. $1.32.

This workbook and the accompanying tests are designed to help students of biology at the secondary school level to master the essential principles of Biology and to suggest various projects and experiments in working them out, so planned as to yield ideas and understandings so necessary in a day of modern science. There are eight units: What is life, Under what conditions can we live, How do living things keep alive, How do parts of an organism work together, How do living things originate, How did life begin, Why cannot plants and animals live forever, and What are the uses of Biology. This last unit illustrates well how we can use Biology to interpret man's health, wealth, and pursuit of happiness. The workbook can be used with eleven texts listed in the references of each of the units studied. Teachers will wlecome the additional activities for use with exceptional children. A workbook by Gruenberg needs no introduction for the name is synonymous with Biology.

—G. O.

STILES, DAN. *High Schools for Tomorrow.* New York: Harper and Brothers, 1946. 212 p. $2.50.

Here is a criticism of the present secondary schools and suggestions for improving them. The author, a former teacher who is now engaged as a motion picture travelog lecturer, secured his information from over a thousand high schools that he visited.

He describes new, constructive, and stimulating programs that he has seen in operation in his travels. Weaknesses of the present academic programs are pointed out and what can be done to correct these weaknesses. The author points out ways our high schools can better train people today to meet the new problems of tomorrow.

Some of the interesting chapter titles are: School All the Time, The Mother Tongue, Education for Family Living, Sex Education, Who Is Delinquent, Are Teachers People, and Should High Schools Teach Religion.

Principals, teachers, school board members, and parents who sense the inadequacy of the present high school program will wish to read this book.

—R. V. M.

PETERSON, HOUSTON (Editor). *Great Teachers.* New Brunswick: Rutgers University Press, 1946. 351 p. $3.50.

"Seeing ourselves as others see us." It would be quite revealing to teachers at times if they could see themselves as their students see them. This is a book written by students about the teacher they liked most. They try to tell why they admired and considered great, the teacher they have written about. One is not only interested in the "great teacher" but in the students, as one analyzes what to them is greatness in a teacher. I doubt if any rated them one hundred per cent as a score card goes, but in ability to teach them to think and to inspire, they all seem to agree that "their teacher" was great. The modern student of today might consider Agassiz, conceited; Woodrow Wilson, arrogant; Garman, queer; and Frederick Jackson Turner as evasive and lacking in courage. Perhaps Turner should have answered as well as asked questions; perhaps there were times when he should have fearlessly passed judgment. And what teacher is there that won't agree that even teachers have their day. A student wrote of the psychologist, William James, "Sometimes Dr. James would put his hands to his head and say, 'I can't think today. We had better not go on with the class,' and he would dismiss us." Twenty-two great teachers are paid tribute to and appraised and of the twenty-two only two are women, Anne Mansfield Sullivan and Lizzie Moore. They were all great teachers as portrayed by those who studied under them.

The great teachers described include: Anne Mansfield Sullivan, James Mill, Lizzie Moore, Moses Woolson, Frederick Sanderson, Mark Hopkins, Charles Garman, Francis Gummere, Woodrow Wilson, Simon Patten, George Burr, John Dewey, Louis Agassiz, William James, Frederick Turner, George Kittredge, Sigmund Freud, Cesar Franck, Theodor Leschetizky, Auguste Rodin, Robert Henri, and Ralph Waldo Emerson.

—F. M. D.

OLSEN, EDWARD G. (Editor). *School and Community.* New York: Prentice-Hall, Inc., 1945. 422 p. $3.75.

Eleven other men collaborated with the author in writing *School and Community* which is the philosophy, procedures, and problems of community study and service through schools and colleges. Ten bridges between school and community are: documentary materials, audio-visual aids, resource visitors, interviews, field trips, surveys, extended field studies, school camping, service projects, and work experiences. The chapters on extended field studies is full of worthwhile material and suggestions for planning and successfully making field trips. Pertinent information on teacher education with emphasis on in-service training of teachers is of interest to teachers and administrators alike.

The community, its population, racial groups and antagonisms, economic status, housing conditions, health and sanitary conditions, social conditions on streets and in homes, recreational facilities, and community consciousness are all factors that so much affect the welfare and success of the school. There is a close correlation between the relation of the school and the community and the happiness and success of the people that live in the community.

—F. M. D.

WOFFORD, KATE V. *Teaching in Small Schools.* New York: The Macmillan Company, 1946. 399 p. $3.75.

The term "small schools" is interpreted to mean those schools taught by six teachers or less. Ninety and nine-tenths per cent of the schools in the United States, of the schools in the states included, are housed in buildings with six teachers or fewer. The teachers in such schools need a practical rather than theoretical book on education because as to length of years in school and preparation for teaching in this respect, the education they have is most often inferior. The teacher is also likely to be young and inexperienced. The young normal school student or teacher will appreciate the four chapters on planning. "Grouping the Children for Instruction," "Planning the Work of the Day," "Planning the Long-View Unit," and "Planning the Daily Lesson."

The modern school is characterized by the self-discipline of the pupils. This is desirable in all schools, but it is an essential in the small one. The teacher has neither the time nor the strength to assume the responsibilities attending the traditional use of authority. Moreover, the practice is poor experience in democratic living. The chapter entitled "Controling Group Living" is intended to assist the beginning teacher with this problem.

Perhaps there is no area in which greater progress has been made in the modern school than in guiding the learning of children. About a decade ago, a book, *The Passing of the Recitation*, by Vivian T. Thayer, appeared, and since that time the recitation, as it has been known in the past, has almost disappeared except for testing purposes. In its stead have come discussions, planning, laboratory activity and creative period. Even drill and evaluating, long considered educational chores, have taken on new forms in the modern school. They are treated in the chapters entitled "Directing the Activity or Laboratory Period," "Leading Discussions," "Drilling for Skills," "Discovering and Developing the Creative Power in Children," and "Evaluating the Learning Process."

Today all the child's experiences are seen as contributing to his learning; hence all are used and directed to desirable ends including community excursions, and the use of the radio.

Two chapters are devoted to these activities: "Using the Radio," and "Taking Excursions."

"Understanding the Community," and "Working with Parents" are chapters completing a book in education that beginning and in service teachers will find most beneficial to read and study.

—F. M. D.

COOPER, RUSSELL M. *Better Colleges, Better Teachers.* New York: The Macmillan Company, 1944. 167 p. $1.25.

This is the resumé of an investigation made by the North Central Association Committee on the Preparation of High School Teachers in Colleges of Liberal Arts. The following twenty-eight colleges participated: Ashland (Ohio), Bethany (Kansas), Bradley (Illinois), Central (Iowa), Cornell (Iowa), DePauw (Indiana), Dennison (Ohio), Drury (Missouri), Dubuque (Iowa), Goshen (Indiana), Hiram (Ohio), Illinois Wesleyan (Illihois), Jamestown (North Dakota), Knox (Illinois), Lindenwood (Missouri), Luther (Iowa), Milwaukee-Downer (Wisconsin), Mundelein (Illinois), Nebraska Wesleyan (Nebraska), Ozarks (Arkansas), Phillips (Oklahoma), St. Olaf (Minnesota), St. Scholastica (Minnesota), Southwestern (Kansas), Wabash (Indiana), West Virginia Wesleyan (West Virginia), Wittenberg (Ohio), and Yankton (South Dakota).

The eight parts of the report are: (1) The nature of this study, (2) The pusuit of objectives, (3) Building the curriculum, (4) The improvement of college instruction, (5) The college personnel program, (6) Professional work in Teacher Education, (7) The contribution of extra-curricular activities, and (8) Working with college faculties.

The study covers a period of three years (1942, 1943 and 1944), but several colleges are still carrying on the investigation. Summer school workshops for participants were held at the University of Minnesota during 1941–1944 inclusive. Much attention is given to objectives, general education, improvement of instruction, counseling, and improvement in education courses and student teaching. College teachers in liberal arts college and those interested in the training and education of teachers will find this study of some significance to their practices and philosophies.

—C. L. D.

JOHNSON, BURGES. *Campus versus Classroom.* New York: Ives Washburn, Inc., 1946. 305 p. $3.00.

Campus versus Classroom is a candid appraisal of the American college. During more than thirty years of teaching at Vassar, Syracuse University, and Union, and as adviser to college administrators from coast to coast, the author became intimately acquainted with the life and work of many colleges. So this book is his academic autobiography as well as his profession of faith as a teacher.

American college life today is big business, and the author with wry, warm humor probes beneath the surface of the multitudinous campus activities which consume most of the average, active student's time and energy. All too often the campus activities leave little time for strictly educational pursuits. Campus activities are all too often the tail that wags the dog.

Part I discusses the attributes of the college-bred man, all kinds of colleges, and campus versus classroom. The author defines a college as "a place where the facilities for acquiring an education are conveniently assembled, in an atmosphere conducive to study—almost any college is a place where one may easily acquire education if one happens to want it and will work for it; and it will be as good on education as one happens to want."

The author makes numerous and interesting comments about big colleges, little colleges, private colleges, church colleges, state colleges, women's colleges, men's colleges, coeducational colleges, liberal arts colleges, agricultural colleges, and so on. Athletic programs, fraternities, sororities, "hell week", proms, honor societies, dances, college publications, campus politics—all have come to have a large place in the student life of many colleges—often to the real detriment to the college's alleged purpose. Athletic subsidization is the common practice of most of the larger schools, only some colleges do it more openly than the others.

Part II discusses his own life as a college student, and his later experiences as first a teacher in a women's college, then in a co-educational university, and finally in a men's college. Here the author comments upon a large variety of topics ranging from classroom teaching techniques, teaching problems, examinations, campus manners and morals, creating, and college publicity and recruiting practices.

Part III discusses educating the emotions and education by degrees. The author states: "Reason's highest obligation, I believe, is to discipline the feelings; in fact, a chief object of all education is to provide that self-discipline and not to seek the enthronement of pure reason as the director of our lives.—Much machinery has been invented to assist the process of 'higher education', and some of this easily becomes obsolete or outmoded, and serves only to obstruct. But because the true educational process occurs just at those points where the minds of student and teacher, and student and student make contact, it succeeds despite all handicaps, here and there, in colleges big and little; or even in single classrooms within many colleges everywhere. Yet the wastage is far too great.—Officers and directors who have no part in the educational process itself, but only in the organization which has grown up around it, may stand in the way. Even such conveniences as build-

ings and grounds, furnishings and equipment, organization and classification cease to aid when they themselves become the centers of attention. 'Education' must result whenever and wherever a teacher and student meet sympathetically, intent upon teaching and learning."

—S. M. A.

MARTIN, LYCIA O. *The Prediction of Success for Students in Teacher Education.* New York: Bureau of Publications, Teachers College, Columbia University, 1944. 110 p. $2.00.

This doctor of education study had as its major purpose to discover certain predictors of success for the students of one state teachers college. The procedures used included a study of the characteristics of the students and an investigation of the college situational factors. The experimental group was the 238 members of the entering class in 1936 at State Teachers College, Trenton, New Jersey. Tests, college marks, college records and personal interviews were used.

The eight most important factors of success about which a student should be informed are first semester marks, written English, objective English, science, high school personality rating, history, high school standing, and mathematics. Special effort should be given to aiding freshmen in every way possible to make the best initial start in college. It is very important to a student that he make high first semester and first year marks. There is a high correlation between what the student does in the first semester and the remainder of his college life. The fact that English, history, science, and mathematics distinguish superior students from inferior ones more than do any other subjects leads to the conclusion that these subjects should be emphasized.

—G. E. D.

SOLJAK, PHILIP L. *New Zealand: Pacific Pioneer.* New York: The Macmillan Co., 1946. 197 p. $2.50.

The "long bright land"—New Zealand welcomed United States forces when they arrived there in the critical days of May–June, 1942. New Zealand is located 1,400 miles from Australia and 6,000 miles from South America. It lies between 34° and 47° S. Lat. Its latitude corresponds to that of the territory lying between Los Angeles and Seattle. Summer extends from December to early March and winter from June to late August. Over the greater part of the country the climate is fairly mild, with an average temperature of 56° in the North Island and 51° in the South Island throughout the year.

Travelers rate New Zealand one of the most beautiful countries in the world. The diversity of scenery consists of gleaming curved beaches, fringed with tall tree ferns and red blossoming trees, volcanoes, geysers, hot springs, and mud volcanoes, and blue and green tinted lakes. On South Island there are waterfalls, fiords, high peaks and glaciers.

A series of photographs showing the beautiful scenery, cone-shaped volcanic peaks, waterfalls, and mountain ranges remind one of our beautiful Glacier National Park and parts of Washington and Oregon. A very full and classified bibliography is given, which will be appreciated. Thirty per cent of the people of these islands are of Scottish descent.

The chapter on Education, Art and the Outdoors (sports) should be of interest to teachers and educators. In the field of political science and Social Science, readers will find the book an excellent source of information. The author states, "Apparently we New Zealanders have failed to make ourselves adequately known to our friends and allies." The book was written for the purpose of better informing other people of the world about New Zealand. A list of questions are given that people ask, showing lack of geographic, economic, and political knowledge of New Zealand. New Zealand could have more people come there to make their homes, and under-population is one of their problems.

The author is a native New Zealander, educated in the colleges of New Zealand. A free-lance journalist and publicity man, he has traveled widely in Australia, England, Continental Europe, the Soviet Union, Canada, and the United States.

—F. M. D.

CALAHAN, H. A. *Geography for Grown-Ups.* New York: Harper & Brothers, 1946. 351 p. $3.50.

The author's father was shocked when he, at ten years of age told him that he had finished Geography. He had studied North America, South America, Europe, Asia, Africa, and Australia. And he asked, "What more is there?" Now he realizes there is much more to learn about Geography and the world in which we live. Geography, too often, the author thinks, is taught only to the very young who cannot grasp its scientific aspects, and he has tried to fill a gap in the education of most well-educated people. The first part of the book consists of the scientific and physical phases of geography. Climate, tides, wind, ocean currents and their effect upon man are discussed. The political, cultural, and economic features of Geography make up the second half of the book. War, Strategic Geography, Geopolitik, the Airplane, Atomic Energy, Change and the Future are all chapter headings and topics that indicate facts and information of interest today. It encourages the use of the globe and atlas as one reads the book which is the work of an experienced navigator making applications of geographic principles.

—F. M. D.

HUTTON, GRAHAM. *Midwest at Noon.* Chicago: University of Chicago Press, 1946. 351 p. $3.50.

It has been said that we are now suffering from a "paralysis of analysis." *Midwest at Noon* is an analysis of the Midwest, its people and economy. If you are interested in "seeing ourselves as others see us," then read this book most interestingly written by an Englishman. In 1937 Graham Hutton came to America's Midwest and spent five of the next eight years in the Midwest, serving as Director of the Office of British Information.

Businessman, teacher, writer, editor, and student of international affairs, Mr. Hutton set about to see the country and study it. He visited all but two of the states of the union and traveled more than 100,000 miles in the Midwest alone.

On the inside covers of the book is a map showing the Midwest states and the date of each state's admission to the Union. We sometimes quibble over just what total area makes up the region known as the Midwest. I think the author's idea of the Midwest is that which is generally accepted by all those "who live in," or "are from" the Midwest. We are well aware that along with all the other exports of the Midwest, men are one of their exports and their influence is found wherever they are. It was this part of the United States, in the Ordinance of 1787 that set forth in no uncertain terms the four freedoms and made them become a living and workable reality. The author appreciates the Middlewest, as he sees good here, bad there, faults as well as virtues. But the light of democracy forever kindled and kept burning there casts its shadow a long way. It is this shadow and light-beam that has lured people to this area from the old world until today it is a veritable melting pot. They are alert to the times in which we live. The author is concerned about the press, the radio, and various factors which may standardize and in the end thwart freedom. "They won't be bulldozed," he says. They will continue to be capable of doing their own thinking. He says they are insulated but not "isolated."

Mr. Hutton came to know the Midwest as no foreigner has ever done and probably better than even a native. He writes appreciatively, understandingly, penetratingly of a region that few easterners really understand or care to understand. Altogether this is an unusually fine book.

—F. M. D.

AHL, FRANCES NORENE. *Audio-Visual Materials in the High School.* Boston: the Christopher Publishing House, 1946. 165 p. $2.50.

During the war the Army and Navy invested one dollar per man on their training aids program. Can American Education afford to appropriate less for its boys and girls? The answer is likely to be that it will spend less than this average but will on the other hand, greatly increase its pre-war expenditures.

This book deals with the general problems involved, and suggest means to correct them if a good program is to be developed in the schools. The cooperation of the one in charge of audio-visual aids with the classroom teachers is of extreme importance. The classroom teacher's part in the program, the problems of projection, the selection and training of competent operators, and finally the problem of securing participation necessary to obtain desirable results are among other problems discussed.

Part II is on special applications to the social studies. Part III discusses *Audio-visual Aids Tomorrow*.

In the final analysis, the author states that success of any audio-visual program depends primarily upon the classroom teacher—her interest, her enthusiasm, her intelligence, and her techniques.

—C. L. D.

RAND MCNALLY. *Current Events World Atlas.* Chicago: Rand, McNally & Company, 1946. 50 p. $0.25.

Although a rather cheap grade of paper is used, the reader gets an unusually large amount of information and many up-to-date maps for his money. Emphasized are the major map changes due to World War II. Included are World War II maps, world air routes, and distances, new boundaries in Europe and Asia, members of the United Nations, and so on.

—F. M. D.

FINAL REPORT BY THE COMMISSION ON TEACHER EDUCATION. *The Improvement of Teacher Education.* Washington: American Council on Education, 1946. 283 p. $2.00.

The Commission on Teacher Education, created in February 1938 and formally dissolved in September 1944, devoted most of its time, energy, and means to the conduct of an extensive field program. Included was a national cooperative study in which a large number of representative school systems, colleges, and universities participated, and a series of state wide cooperative studies involving the teacher education interest of ten states. *The Improvement of Teacher Education* concluded the series of eight reports resulting from this study. Here the Commission summarizes what it did, lists the more significant findings, and sets forth its own recommendations.

Among the leading issues and promising trends are those relating to the conditions of teaching (salaries, occupational security, and in-service program of teacher education), recruitment and selection of teachers (very critical) preparatory programs, in-service programs and interinstitutional cooperation. General education promises to become one of the leading objects of educational reform during the

coming years. There is a trend toward better integration in professional education, increased emphasis upon the study of communities and their problems and in bringing about better provisions for understanding child growth and development. Student teaching problems are being re-examined.

—R. J. A.

CASWELL, HOLLIS L., Editor. *The American High School.* New York: Harper and Brothers, 1946. 264 p. $3.00.

The co-authors of this eighth yearbook of the John Dewey Society are the following well known educators: Stephen M. Corey, Donald P. Cottrell, Hamden L. Forkner, Will French, J. Paul Leonard, Gordon N. Mackenzie, and Harold Spears.

The purpose of the book is to analyse the status and needs of American youth, with particular attention to the contribution which the high school can make to their education and effective transition into adult life.

The problem which emerges in comparing the requirements of youth to the offerings and results of typical high school programs is stated in the early chapters. This is followed by an appraisal of current efforts in high schools to meet the problem, and numerous proposals for curriculum change in the future. Attention is given to the training of teachers for tomorrow's high school and to the problems of organization and administration.

This is an excellent book for anyone who is interested in the trend of secondary education. It is well written and presents the thinking of these recognized authorities in the field of education.

—R. V. M.

WARTERS, JANE. *High-School Personnel Work Today.* New York: McGraw-Hill Book Company, Inc., 1946. 277 p. $2.50.

This book is written primarily for high school administrators, teachers, and specialists who are interested in student personnel work. The author attempts to present a synthesis of the current theories on personnel work, to indicate their strong and weak points, to show similarities and basic agreements, and to smooth out the wrinkles that may be causing the secondary school people to trip in their thinking about high school personnel work today. The author's aim is twofold: to bring together in a single volume the more important concepts of personnel work, and to coordinate these concepts in order to assist high school workers to handle more adequately certain pressing problems of student guidance.

The author, who has had much experience in this important field of education, narrows the gap

between theory and practice in this practical book. Secondary teachers and all others doing personnel work will be interested in this new book.

—R. V. M.

LEONARD, J. PAUL. *Developing the Secondary School Curriculum.* New York: Rinehart and Company, Inc., 1946. 560 p.

The secondary school can no longer delay facing the fact that it must bring its curriculum and organization into harmony with its changed student population and functions. The major purpose of the secondary school must shift from preparation for college entrance to the development of competence in citizenship for all youth. The high school today is the one place where youth of all races and from all social and economic classes are learning to live together in a democracy.

The major purpose of the book, according to the author, is to assist students in institutions for teacher education, and teachers and administrators in school systems who want to study the ways of reorganizing the curriculum of the school. This book provides suggestions and illustrations for those who wish to reorganize by retaining the subject classifications; it also suggests appropriate materials and techniques for those who wish to cut across existing subject boundaries.

This book is well written and is recommended to all who are interested in the field of the secondary school curriculum.

—R. V. M.

PLEASANTS, HENRY, JR., M.D. *If You Ask My Advice.* Boston: Bruce Humphries, Inc., 1946. 110 p. $2.00.

The author of this book, a well known author-physician, presents certain important problems of life. In plain, understandable language he attempts to bring doctor and patient, or doctor and anxious family, down to a common level in the analysis of these subjects. He attempts to encourage the reader to develop in himself a sound philosophy of life in which his sense of relative values will be more perfectly adjusted. The frank discussions of family problems are treated in a lighter vein than is usual in a book of this type, with colorful character sketches to give human interest appeal.

The varied collection of eight articles contained in the book are Insanity in the Family, The Problem Child, Child Discipline, This Thing Called Sex, The Alcoholic, The Drug Addict, Financial Security, and Vacations.

—R. V. M.

NEWMAN, BARCLAY M. *Vitalized General Science.* New York: College Entrance Book Company, 1947. 380 p.

This is a paper covered volume but packed full of information. The work is divided into 20 chapters. At each chapter end is a summarized review under the heading, "What we have learned in this chapter." This is followed by a list of questions. The book is illustrated by line cut diagrams and many striking cartoons. Certain features of the illustrations are emphasized by being printed in color. The book is heavily weighted on the side of physical science. There are only 80 pages of biological to 300 pages of physical science. We would have liked to see atomic energy expanded to a much greater extent, but for general basic science it serves a useful purpose.

—W. G. W.

SKILLING, W. T. AND RICHARDSON, R. S. *Sun, Moon and Stars.* New York: Whittlesey House, McGraw-Hill Book Company, Inc., 1946. 274 p. $2.50.

The authors call this a book on astronomy for beginners. It is a popular treatise of the moon, sun, planets, stars, famous astronomers, and observatories. The style and vocabulary are suited to junior and senior high school boys and girls. The difficult words are pronounced for you. The good points of this book are the absence of technical terms, the interesting style of writing, and the fact that all the information is up to date. There are 93 illustrations.

—W. G. W.

HAUPT, ARTHUR W. *An Introduction to Botany.* New York: McGraw-Hill Book Company, 1946. 425 p. $3.50.

This book was prepared for the purpose of giving the college student the basic facts and principles of plants. With this foundation he can understand structure, functions, life relations, and evolution. Of particular value to the student who will not continue with advanced courses are the topics on evolution, heredity, adaptation, and economic botany. The whole treatment is cultural rather than technical. There are 289 illustrations. At the end of the book is a list of visual aid films.

—W. G. W.

STILL, ALFRED. *Soul of Lodestone.* New York: Murray Hill Books, Inc., 1946. 233 p. $2.50.

The magic of magnetism or the soul of lodestone has exercised the thinking mind of man of many lands throughout thousands of years. This book gives an account of the beliefs and theories of the early philosophers regarding the nature of lodestone. Here we have the story of the origin of the magnetic compass, the work of William Gilbert, and the mapping of the lines of force of the earth. The many quotations from a wide range of early and medieval scientists make this book interesting and stimulating.

—W. G. W.

MILLARD, NELLIE D. AND SHOWERS, MARY JANE C. *Laboratory Manual of Anatomy and Physiology.* Philadelphia: W. B. Saunders Company, 1946. 119 p. $1.00.

The exercises of this manual include the study of living animals, dissection of fresh and preserved specimens, microscopic examination of living and prepared tissues and investigation of physiological phenomena. There are thirty of these exercises with enough material for a two-hour period. A summary is written by the student on completion of each exercise providing for the rethinking and organization of subject matter so essential for learning. There are thirty-six illustrations. An outline for teachers accompanies the manual.

—G. O.

MCCLUNG, L. S. Laboratory Manual, *General Bacteriology.* Philadelphia: W. B. Saunders Company, 1946. 106 p. $1.25.

This manual is designed as a work book of laboratory exercises for classes in introductory bacteriology. The experiments are designed to illustrate certain fundamental principles of bacteriology and to introduce the student to essential techniques. Procedure details are limited to a few statements and provision is made for the recording of results. There are 61 exercises. Instructors will find instructions in the appendix helpful for laboratory techniques and supplies. Ample space is provided for drawings.

—G. O.

VANCE, B. B., BARKER, C. A., MILLER, D. F. *Biology Activities.* Chicago: J. B. Lippincott Company, 1946. 316 p. $1.20.

This workbook may be used with any biology text since reference is made to twenty standard texts. The contents of the text are well-thought out and organized. However, I believe many teachers would reverse the sequence of Unit I and Unit II, for the reason that "Afield with the plants, flowers, fruits, and seeds" is such a challenging way to begin interest in living things; for, while they are afield, they will run into insects and thus start those permanent collections for later lessons in-doors. The organization of the rest of the material is excellent. The illustrations are not only good but useful to the student. Much thought has been given to the unit reviews and student self-tests, and a pupil record helps the pupil himself to keep his score. Two projects are carefully outlined at the close of the workbook, an insect collection and a leaf collection. Others are provided in the teacher's manual.

—G. O.

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